7 APPENDICES

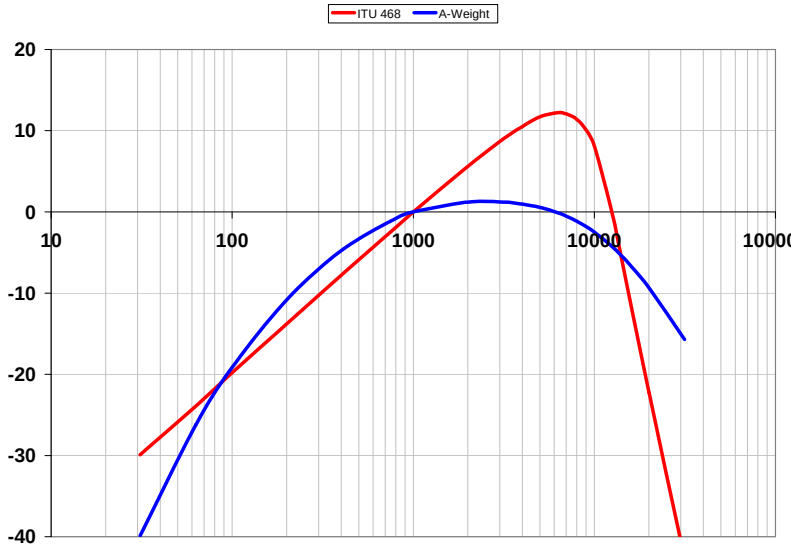
7.1.1 Listener Noise Tolerance Study

A cornerstone of radio allocations is understanding that a particular RF signal-to-interference (protection) ratio yields a desired audio signal-to-noise ratio. In the U.S., however, minimum audio SNR standards for FM stereo reception are not available. The purpose of this test was to determine how consumers would rate audio samples with various types and levels of noise impairment and at what audio SNR consumers would turn off the radio because of the impairment. Three different kinds of interference were tested at five different levels. Seven different audio clips were used to simulate all possible types and styles of broadcasts.

The audio noise meter chosen for this study complies with the ITU-R 468 standard, which combines a quasi-peak reading audio voltmeter with a frequency-weighting curve to objectively measure audio noise similar to the human ear. This instrument, sometimes called a "psophometer" is widely used when measuring noise in audio systems, especially in the UK and European countries.

Most audio engineers are familiar with the A-weighting curve, which is said to reflect the 'equal-loudness contours' derived initially by Fletcher and Munson (1933). However, these curves relate only to the subjective loudness of pure tones, not noise. Developments in the 1960's, spread by audio tape recording and FM broadcasting, indicated the need for a better weighting curve. The ITU R 468 curve was developed to better match the ear's response to low-level noise. As shown in Figure 9, the curve rises at a 6 dB/octave rate to 6.3 kHz, where it has 12 dB of gain (relative to 1 kHz). From here, it quickly attenuates high frequencies at approximately 30 dB/octave.

Figure 9 - Frequency response curves for ITU 468 (red) and A weighting (blue); vertical scale in dB, horizontal in Hz



It is important to note that the ITU 468 specification uses a very special quasi-peak rectifier with carefully devised dynamics (A weighting uses RMS detection). Rather than having a simple 'integration time' this detector requires implementation with two cascaded 'peak followers', each with different attack time-constants carefully chosen to control the response to both single and repeating tone-bursts of various durations. This ensures that measurements on impulsive noise take proper account of the ear's reduced hearing sensitivity to short bursts. The ITU 468 measurements are referred to herein as a weighted quasi peak signal-to-noise ratio (WQPSNR).

Seven audio samples were processed with three types of interference (pink, white Gaussian, and USAI pulsed) at five WQPSNR levels (45, 40, 35, 30, and 25 dB). Additionally, an unimpaired reference sample of each clip was included for a total of 112 clips presented to consumers. Audio samples lasted between 15-20 seconds. They included a low density music selection (e.g., Edward Gerhard's "If I Feel/In My Life"), a medium density music selection (e.g., Jimmy Buffet's "I don't know and I don't care"), a high density music selection (Fleetwood Mac's "Go your Own Way"), a female-voice commercial for NPR's "Fresh Air", a male-voice commercial for NPR's "Morning Edition", a passage of female speech from NPR's "All Things Considered", and a passage of male speech from "All Things Considered".

In order to generate audio samples for listening sessions, the reference samples were passed through a Telos Omnia processor for standard broadcast level processing and compression. The composite analog stereo FM signal of the Omnia was modulated by a Hewlett Packard 8647A signal generator that served as the "desired" signal source. The resulting signal was then mixed with lower first adjacent channel RF signals to generate varying degrees of audible impairments to the desired signal. These interfering signals were produced by the combining the FM generator with a hybrid (HD Radio) signal, produced by a Harris Dexstar exciter at the standard 1% power ratio. The analog FM signal was modulated as follows:

- Modulated with audio pink noise and set to a level that caused an FM modulation monitor to indicate 100% modulation peaks at about ten second intervals.
- Modulated with white Gaussian noise and set to a level that caused an FM modulation monitor to indicate 100% modulation peaks at about ten second intervals.
- Modulated by pulsed USASI noise at a level that caused an FM modulation monitor to indicate 100% modulation peaks.

A Pioneer model VSX-D814 home theater receiver was used to receive the resulting signal. The audio samples were then recorded directly to an audio CD-R disk.

Thirty listeners (12 males and 18 females) between the ages of 21 and 65 were recruited for this consumer test. Fifteen of the participants (4 males and 11 females) were employees of National Public Radio. They were contacted through a mass email to all National Public Radio staff. The other 15 participants (8 males and 7 females) were recruited via a posting on websites.

Testing was held in Broadcast Studio 5A at National Public Radio Headquarters in Washington D.C. A Dell Dimension GX870 with a Samsung Sync Master 765MB monitor were used to run custom testing software to administer the test. A Creative Sound Blaster Audigy LS sound card converted the wave files to analog audio, which were sent to an APHEX Model 124A

audio interface unit. This output of the interface unit was carried by balanced XLR audio cables to the stereo pair of Mackie HR 824 self-amplified professional monitor speakers that provided the audio stimulus for the test.

Speech was the most susceptible to interference. At the worst interference level (25 dB) speech was rated at .94, slightly below "bad", compared to 1.16 for Commercials and 1.97 ("poor") for Music. Ratings gradually got better as signal/noise ratios improved. Rating differences between 45 and 40 dB appeared, but were fairly small. Sharper differences occurred at 35 dB, and in the speech genre mean scores begin to drop below 3.0, numerically equivalent to under "fair". By 30 dB all genres are clearly negatively affected, with participants rating all audio below 3.0.

Table 9- Overall Quality Scores

Interference	Level	Commercial	Music	Speech	Total
NRSC	-45	3.8	4.1	3.7	3.9
	-40	3.8	3.9	3.1	3.6
	-35	3.2	3.6	2.3	3.1
	-30	2.5	3.0	1.6	2.5
	-25	1.5	2.2	1.0	1.7
Pink	-45	3.9	4.2	4.0	4.0
	-40	3.5	3.8	3.5	3.6
	-35	2.7	3.4	2.4	2.9
	-30	2.0	2.7	1.5	2.1
	-25	1.0	1.8	0.9	1.3
WGN	-45	3.8	3.9	3.9	3.9
	-40	3.4	3.0	3.0	3.5
	-35	2.6	3.6	2.3	2.9
	-30	1.7	2.8	1.7	2.2
	-25	1.0	2.0	0.9	1.4
	Unimpaired	4.0	4.2	4.6	4.3

The results show that the number of participants expressing annoyance at each signal-to-noise level. For all audio samples, at 25 dB an overwhelming majority of people express that they heard extremely annoying or annoying background noise. At 30 dB the majority of participants now express hearing slightly annoying or annoying background noise. In the speech genre, however, a majority still report hearing annoying or extremely annoying noise. At 35 dB, the picture changes substantially. Now, for commercials only 22% report that the noise was extremely annoying or annoying. For music, only 15% report the noise as extremely annoying or annoying. For speech, most affected by interference, 37% still report the noise as

extremely annoying or annoying. In all cases, the MOS and Annoyance scores are negatively correlated – the more annoying the background noise, the lower the MOS.

With regard to leave-on rates, both MOS and annoyance scores were correlated. MOS to Leave-on was positively correlated, and Annoying to Leave-on was negatively correlated. Table5 shows the signal-to-noise ratio of interference and the percentage of people claiming they would keep the radio on. Notice that for the 45 and 40 dB levels almost all listeners would keep the radio on. At the 35 dB level, the percentage of listeners reporting that they would leave their radios on is still very high. However, once again speech is the most affected by the interference as evidenced by the percentages of people keeping the radio on. At the 30 dB level of interference, all three categories of genres are negatively affected by the interference with the majority of participants claiming they would turn off their radio.

In this study we examined listeners' attitudes towards audio that was recorded at different signal-to-noise ratios. We first asked them to rate the audio using a modified ITU-R recommended MOS scale. We then asked them to identify background noise and rate how annoying it was. Finally we asked them to tell us the point at which they would turn off their radio, given the background noise in relationship to the desired signal.

We found that participants were sensitive to background noise, as shown by the increasing displeasure as more noise was inserted on the desired signal. This was particularly apparent for speech, which allows more background noise through than dense audio, such as processed music. Mean opinion scores showed that at approximately 35 dB WQPSNR people were becoming no longer satisfied with audio, rating it "fair". At 30 dB listeners became so discontent that they rated what they heard as "poor".

Participants rated noise slightly more favorably, with the greatest number of complaints coming at 30 dB. Although at 35 dB a majority of participants heard noise, the largest percentage claimed it was "slightly annoying" rather than "annoying" or "extremely annoying". At 30 dB, however, an overwhelming majority began to strenuously object to the background noise, especially when listening to speech.

Interestingly, listeners were more likely to complain about the audio in their quality ratings than they were willing to turn the radio off. Although listeners rated audio at 35 dB WQPSNR as fair (3.0), over 80% claimed they would continue to listen to the program. Percentages were particularly high when they were listening to music and commercials. At 30 dB, when listeners were now claiming that the audio was poor (approximately 2.2), approximately 60% were claiming they would leave the radio on. Thus, participants seemed most prone to changing their behavior (turning off the radio) when noise reaches a level typically heard at 30 dB or 25 dB WQPSNR.

Our laboratory testing of receivers measured all audio signal to noise ratios for every D/U condition. The D/U results were extracted at 30, 40 and 50 dB WQPSNR. In our mapping studies we used the D/U ratios derived from the 40 dB results for several reasons. First, the results of the listener noise testing indicated an impairment midway between these audio impairment targets. Second, the 35 dB WQPSNR was rated only "fair" overall, and we chose the next higher standard. Third, and particularly relevant to mobile and portable reception, the field strengths are predicted for a median, but fading will occasionally produce lower audio SNRs. Determining maps with D/Us based on 40 dB WQPSNR ensured that with mobile and

portable fading the reception quality would drop below the nominal 35 dB value to an acceptable degree.

7.2 Measurements of Indoor and Portable IBOC DAB Reception

Measurements of IBOC DAB reception for indoor and portable service were collected with the full instrumentation developed for mobile reception, discussed in our July 27, 2007 report. This system collected four signals simultaneously: the IBOC DAB receive status, the field strength of the IBOC host FM, and the field strengths on the upper and lower first-adjacent channels. The portable system, shown in Figure 10, was mounted to a small four-wheel cart that provided easy movement over a variety of surfaces and through doorways. The cart included a generator connected to the right-front wheel, to record the speed and distance traveled. This was especially important to check if any data was recorded at a stop, which should be removed from the measurements.

Figure 10 - Portable signal measurement system

To reference the measurements to the field strength prediction model a receiver faded performance threshold (FPT) was applied to the link budgets in Table 10 and Table 11. The basic formula for the link budgets is:

FPT=Vi + Nr + Cd/No + IBACr + Kd + C - G + L + Lf

where the coefficients are as listed in the left column.

Using kTB with an equivalent noise power bandwidth of 140 kHz (both 70 kHz carrier groups combined) the thermal noise bandwidth Vi, of the receiver is -152.5 dBW. The noise figure of the receiver is estimated from performance tests and literature published by the manufacturers of tuner modules.

The carrier-to-noise value is taken from laboratory measurements of receivers, which determined that a *C/N* of 3 dB was required to exceed threshold of audibility (TOA) impairment. This value may be expressed in *Cd/N*, a form used by iBiquity Digital Corp., as 55.1 dB-Hz. Since the carrier power is expressed in dBm the thermal noise of the receiver is converted to the same units. Normalization is made to Cd/N, where N is across one Hz, to the

receiver noise bandwidth B, which is combined with the noise figure Nr for the required input power in dBm. It is NPR Labs' practice to express RF signal levels for testing and mapping in terms of the field strength of the analog host. Thus, 20 dB is added to the required input power for the required analog host FM power.

The next section of the link budget converts the signal power into field strength by first calculating the dipole factor at 90 MHz (the middle of the FM Reserved Band, which most public radio stations operate), to which the 50 ohm dBm-to-dBu conversion factor C is added. The antenna gain relative to a dipole is based on NPR data and discussions with automotive receiver manufacturers.

Table 10- Link budget for indoor reception

k	Boltzmann's constant	1.38E		W/K
T	reference noise temperature	290		degr
B	noise equivalent bandwidth of input of both carrier	140,0		Hz
Vi	thermal noise of receiver bandwidth	-		dBW
			-	dBm
N	noise figure of receiver input, estimated		7	dB
C d/	minimum CNR for acceptable service (Gaussian Noise for TOA)	55.1		dB-Hz
	normalization of Cd/N from 1 Hz to *B*		3.6	dB
	required input power	-		dBm
IB	1% IBAC ratio adjustment		20	dB
	required analog host FM power	-91.9		dBm
f	frequency of operation		90	MHz
K	dipole factor [20·log(9.73/(λ√*G*)], where *G*=1.64		7.2	dB
C	dBm (50Ω) to dBuV conversion factor		10	dB
	antenna gain relative to dipole, (500mm whip, BBC		-15	dB
L	transmission line loss		0	dB
L	building loss factor, 50th percentile, (single-story,		9	dB
Lf	location variability factor (20% likely to exceed		8.4	dB
F	incident field at 1.5m rcv. height		55	dBu

The result is the incident field strength at the building in the absence of other RF noise. (It should be noted that this field strength is not comparable to the FCC's F(50,50) curve predictions due to differences in reference height (9.1 meters vs. 1.5 meters). Also, the field strength is reduced due to the effects of signal scattering and absorption at low antenna heights.)

Table 11- Link budget for portable reception

k	Boltzmann's constant	1.38E-		W/K/Hz
T	reference noise temperature	290		degrees
B	noise equivalent bandwidth of input of both	140,000		Hz
Vi	thermal noise of receiver bandwidth	-152.5		dBW
			-	dBm
Nr	noise figure of receiver input		8	dB
Cd/N	minimum CNR for acceptable service (9-ray terrain-obstructed for TOA) (1.0% BER, urban fast fading, ref. Cd (dBm)	61.4		dB-Hz
	normalization of Cd/N to 1 Hz		9.9	dB
	required input power	-104.6		dBm
IBACr	1% IBAC ratio adjustment		20	dB
	required analog host FM power	-84.6		dBm
f	frequency of operation		90	MHz
Kd	dipole factor [$20 \cdot \log(9.73/(\lambda\sqrt{G})$], where		7.2	dB
C	dBm (50Ω) to dBuV conversion factor		107.0	dB
	antenna gain relative to dipole (BBC 1990,		-20	dB
L	transmission line loss		0	dB
LB	building loss factor, 50th percentile, (single-story, 90 MHz, Skomal & Smith)		9	dB
Lf	location variability factor (20% likely to		8.4	dB
FPT	incident field at 1.5m rcv. height		67	dBuV/m

The link budget tables include a median building loss at 90 MHz and a location variability factor to adjust to 80 percent of the best locations (i.e., 20 percent of locations are expected to exceed this loss factor).[8] These tables indicate the incident field required at the exterior of a building, which accommodates prediction with NPR Labs' pathloss model mapping.

The indoor and portable link budgets follow the same layout as for vehicular reception, except without the adjustment for environmental noise. Since these tables include additional losses for building penetration and location variability, we find that the required field strengths exceed the (outdoor) environmental noise predicted by ITU-R P-372. Although local sources of indoor noise may elevate the RF noise level substantially and require higher minimum field strengths, these are potentially-correctable by the listener, at least in the case of fixed indoor reception.

A variety of antennas were considered for the indoor measurements. First, we needed accuracy that could be calibrated and maintained. Second, we wanted compactness so the antenna could be carried easily and moved through cluttered areas and doorways. Third, we wanted efficiency, which is usually requires size. A quarter-wave monopole, such as used for the mobile measurements would be a poor candidate; without a large ground plane the antenna's gain would not be stable.

A normal-mode helical antenna was chosen for indoor measurements. It provides the best sensitivity among compact antennas, and is relatively easy to build. It was constructed with ½"

[8] Skomal, Edward and Smith, A. A.: *Measuring the Radio Frequency Environment*, Van Nostrand, Reinhold Company Inc, 1985.

diameter PVC tubing and tinned 22-guage wire, and fitted with a BNC connector at the base, which contained a series capacitor to compensate for inductive reactance. A small stainless steel disc was added to the base to serve as a counterpoise, improving the gain and making the antenna quite immune to proximity effects of the person holding the antenna.

Figure 11 - Portable/indoor antenna

The completed antenna is shown in Figure 11. The counterpoise was fitted with a BNC bulkhead connector that allowed attachment of the cable connected to the monitor receivers. This antenna behaved in an omnidirectional manner, which is desirable for indoor and portable measurements. The antenna design is a slow-wave structure with a velocity ratio of approximately 4:1, which allows it to respond as a linearly-polarized vertical antenna. Since the broadcast station used for measurement (WAMU, Channel 203B, Washington DC) transmits circularly polarized signals, this antenna responds to the station's vertically polarized emissions, which are equal to the horizontal emissions.

The antenna was tested at the Potomac Overlook on the George Washington Parkway, west of Washington DC, where the emissions from WAMU and several other FM stations are unobstructed. Of equal importance, the steep slope of the bank above the Potomac River minimizes the effect of ground reflections from the stations. Comparison with the Potomac Instruments ANT-71 reference antenna determined that the helix system was approximately 9 dB below an ideal dipole. This corresponds closely to the theoretical performance of the design.

WAMU employs a pole-mounted Shively Laboratories circularly-polarized transmitting antenna. Its design provides a highly circular horizontal-plane radiation pattern, providing field strengths from the station that can be relied upon at any desired indoor test sites.

IBOC DAB reception was measured at 11 locations in the Greater Washington DC area, as summarized in Table 12. The sites included condominium and office buildings, homes and shopping malls. The distances and bearing from WAMU are listed, along with the field

strengths incident on the exterior of the building at ground level. In most cases several measurements were collected at different locations in the buildings; Table 12 shows one of these locations for each site, as shown in the Notes. The building penetration loss associated with these interior locations is provided. A map of WAMU's site and the 11 measurement sites is shown in Figure 12.

Table 12 - Selected results from indoor IBOC receive measurements at 11 sites

Location	Notes	Dist (km)	Azimuth (deg T)	Exterior Field (dBu)	Bldg. Loss (dB)	IBOC Availability (%)
WAMU	transmitter site	0	0	-	-	-
301 N Beauregard St, Alexandria VA	high-rise condo. 2nd floor	13.4	196	68	15	98
721 Gibbon St, Alexandria VA	brick townhouse ground floor	15.6	166	56	-	96
Fair Oaks Mall Fairfax VA	shopping mall, upper deck	24.3	250	55	19	9
445 12th Street SW Washington DC (FCC HQ)	office building, 2nd floor	8.2	138	68	10	100
1316 N Quintana St Arlington VA	brick house, basement	7.8	221	72	11	100
2110 Duke St. Alexandria VA	office building, 4th floor	14.8	170	65	9	68
1771 N St NW Washington DC (NAB HQ)	office building, 2nd floor	5.5	126	72	15	100
635 Mass Ave NW Washington DC (NPR HQ)	office building, 2nd floor	7.3	121			74
Springfield Mall Springfield VA	shopping mall, upper deck	19.2	201	52	11	3
Tyson's Corner Mall Vienna VA	shopping mall	11.2	258	73	15	72
2775 S Quincy St Arlington VA (WETA HQ)	office building, 8th floor	10.6	177	65	19	58

The IBOC Availability in Table 12 shows the percent of time that IBOC was received while moving through the buildings at the indicated location. While these measurements could be considered portable, the gain of the measurement antenna was equivalent to the antenna assumed in the Indoor Link Budget of Table 10. The movement, at slow walking speed, avoided the effects of interior standing waves and provided a means of spatially averaging the receiver performance.

Figure 12- Map of indoor measurement sites and WAMU transmitter

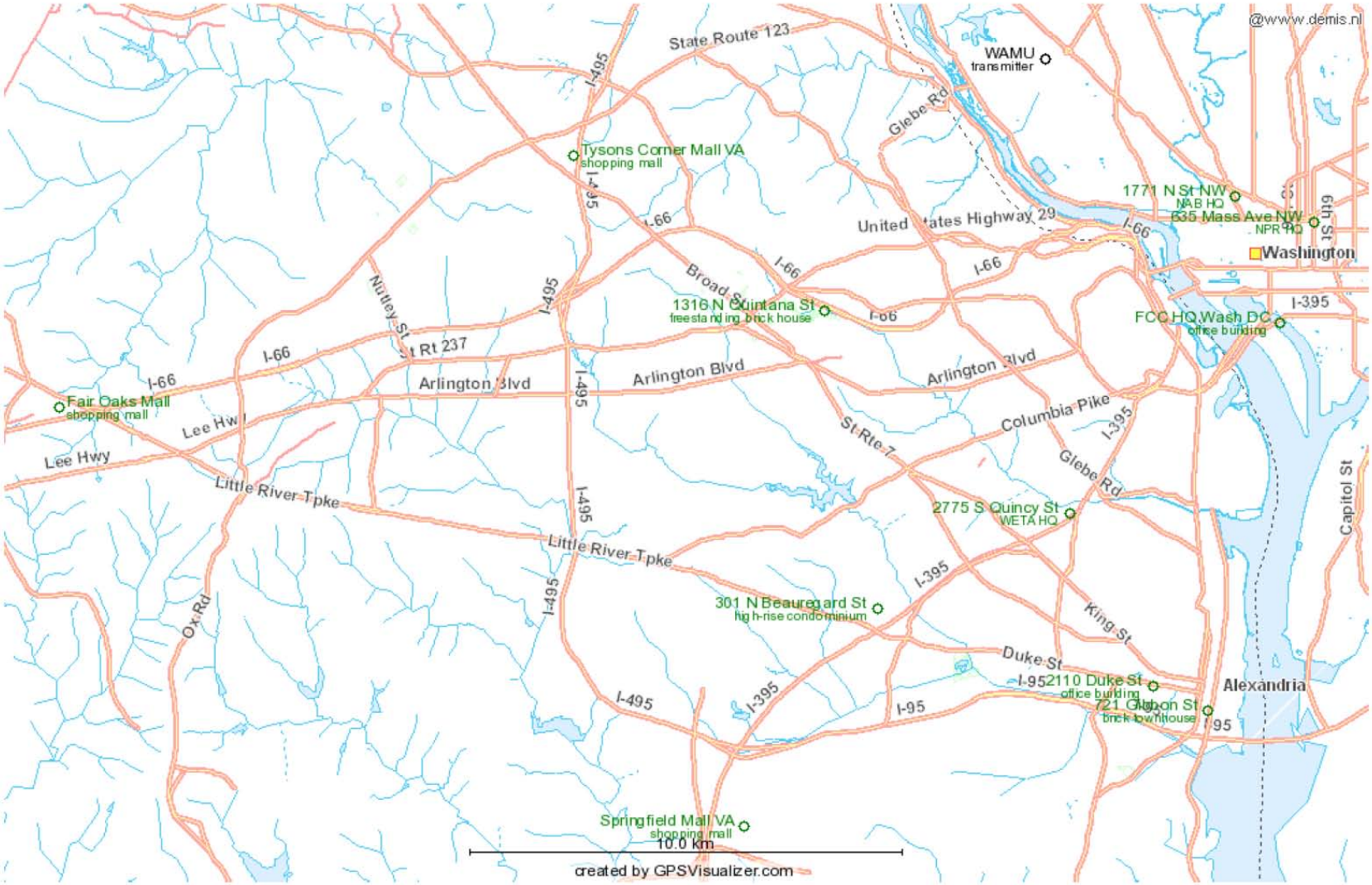
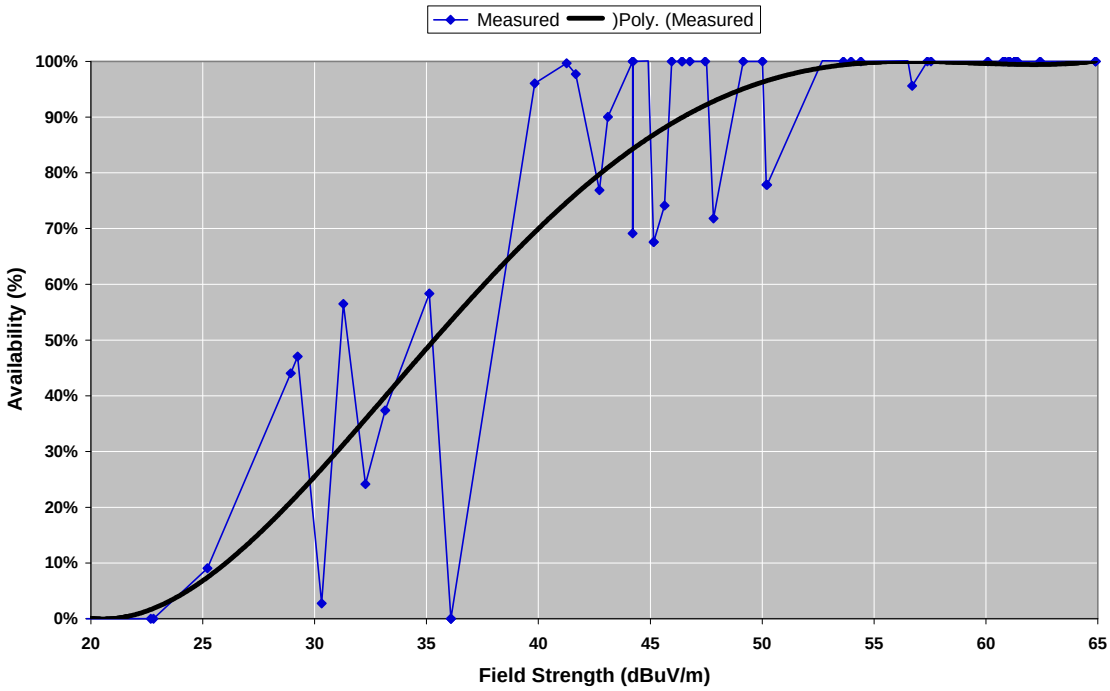


Figure 13 -Indoor-portable HD Radio reception availabilty vs. indoor field strength

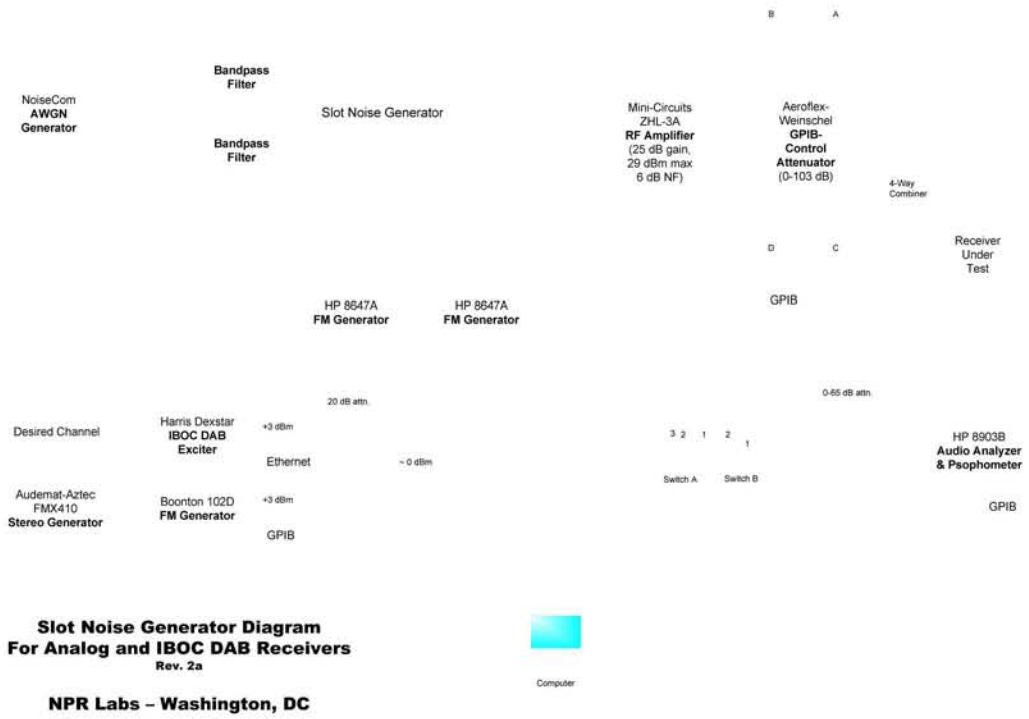


The results of all 50 indoor measurements from the 11 sites are graphed in Figure 13. The blue dots indicate the percentage of time and locations at which IBOC DAB was received (on the vertical axis) against the mean field strength collected for each interior location. A 4th-order polynomial trend line, in black, helps show the overall field strength required for availabilities from 0 to 100 percent. It is apparent that for an availability of 80%, as assumed in the Indoor Link Budget, a field strength of at least 42 dBuV/m was required for indoor IBOC reception. This compares to the link budget's estimate of 37 dBu (after removing the 9 dB penetration loss and 8.4 dB variability factor from the exterior field of 55 dBu). Since the antenna was later found to have slightly more loss than the -15 dBd antenna in the link budget, we consider these limited indoor tests and the calculated field to be in substantial agreement.

7.3 Receiver-Induced 3rd-Order Intermodulation – Slot Noise Generator Study

In populous areas of the U.S., the proliferation of high field strengths in the FM band can lead to desensitization of receivers, known as receiver-induced third-order intermodulation effect (RITOIE). This effect occurs when numerous strong carriers, widely separated in frequency from the desired station, intermodulate (beat together) to produce a myriad of new products, some of which fall within the desired channel and produce elevated noise levels. This RITOIE noise can mask the reception of weaker stations that would otherwise be receivable. The only solution for superhetrodyne receivers is to put additional preselection (RF filtering) ahead of the RF amplifier and mixer stages - an expense on which receiver designers often skimp. The high sensitivities of modern FM receivers has aggravated this problem.

Figure 14 - Slot Noise Generator developed to measure RITOIE



Generating many strong signal carriers to create the effect of a crowded FM band is not practical, and the result would be affected by the specific frequencies and amplitudes chosen. A more general-purpose and repeatable design was required. After thorough research into various techniques an obscure design was discovered.[9] This device was named a "slot noise generator" (SNG) by its developer, and uses broadband noise to simulate the effect of many strong FM carriers. NPR Labs' implementation of the SNG is show in Figure 14. The heart of

[9] "A High-Performance FM Receiver For Audio And Digital Applications", Wayne C. Ryder, RFDesign Magazine, October 2000.

the device is within the dashed lines, and comprises two high-performance bandpass filters having a center frequency of 6 MHz and a bandwidth of 8 MHz. A RF white noise generator is connected to both filters, and the outputs are each are connected to separate high-power mixers that up-convert the noise spectra to the FM band.

Figure 15 - Spectrum of slot noise generator with desired carrier at center of trace

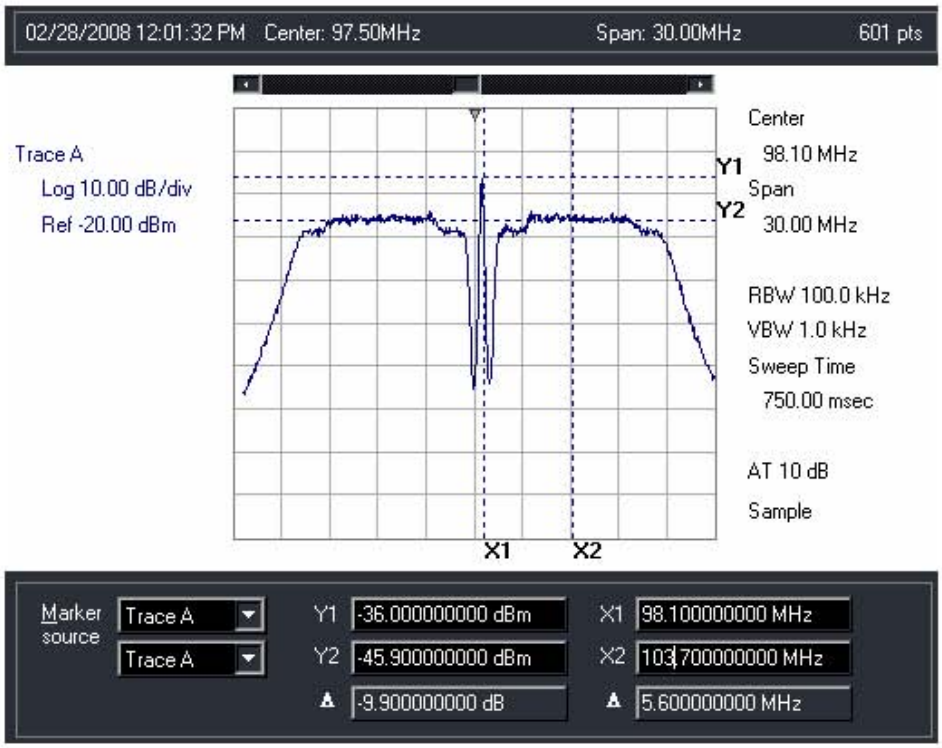


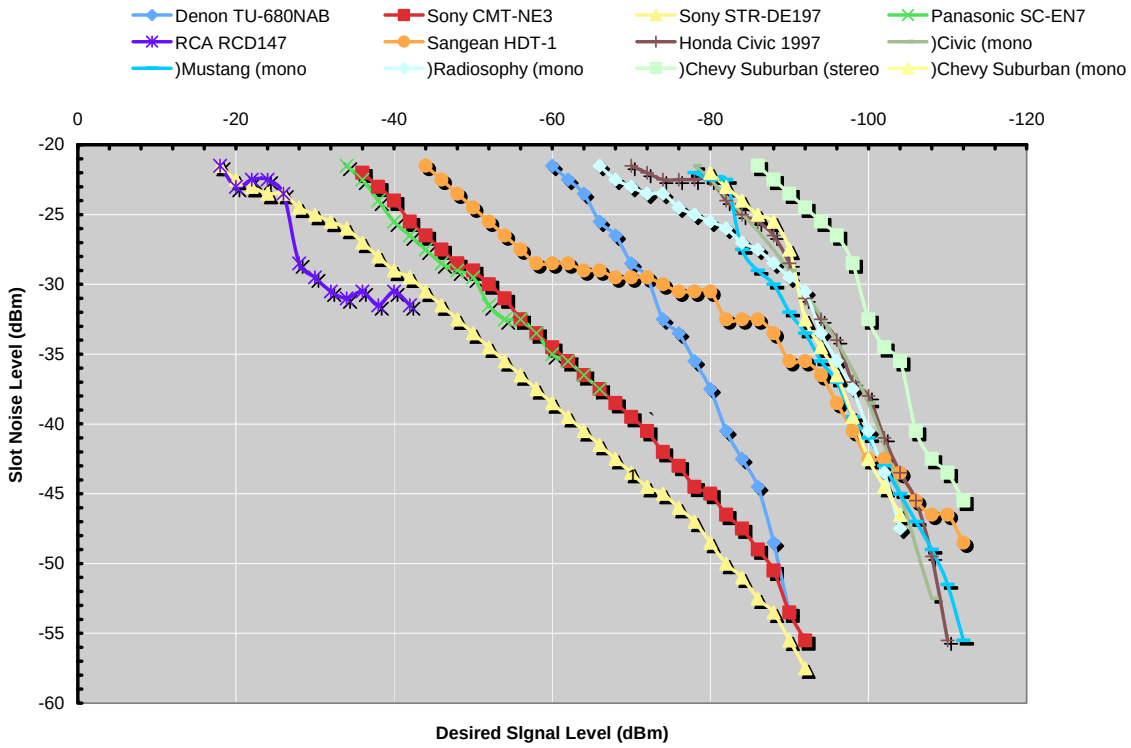
Figure 15 shows a spectrum analyzer trace of the SNG over a 30 MHz span, centered on 98.1 MHz. The noise appears as two plateaus, with a deep "slot" between the upper and lower bands. In this quiet slot the desired carrier is shown. This particular trace shows the desired carrier at 98.1 MHz rising slightly above the noise plateaus.

The slot noise generator is operated by first lowering the noise plateaus and raising the desired carrier to the receiver's target audio SNR. This is the sensitivity threshold of the receiver. Next, the noise plateaus are raised and the desired carrier level is increased until the receiver's SNR again meets the target value. (This assumes the receiver is affected by the noise plateaus. An ideal receiver would reject this out-of-channel noise and its sensitivity would be unaffected.) This process is repeated until enough measurements are available to observe the relationship between sensitivity and plateau noise power over a wide dynamic range.

Figure 16 illustrates the test results with several consumer receivers. An ideal receiver would produce a vertical line, that is, its sensitivity threshold on the X axis would not change as the noise level is increased. All of the receivers exhibit various degrees of degradation. The Denon TU-680NAB tuner is the most vertical, showing a reduction in sensitivity of approximately 15 dB as the noise is increased more than 30 dB. The Sony STR-DE197 home

stereo receiver, by contrast, changes its threshold 70 dB over the same range of plateau noise, indicating that it would experience substantial loss of sensitivity.

Figure 16 - SNG test results of several consumer receivers



In Figure 16 some receivers were tested in stereo and some in monophonic mode, as indicated in the legend. The monophonic tests provide a higher sensitivity, placing their graph lines farther to the right, at lower desired signal levels. The stereo and monophonic RITOIE performance is relatively similar, as expected. Currently, no method exists for translating SNG measurements into a prediction of receiver behavior, as the prediction would require knowledge of the level and frequency of every out-of-channel FM signal. However, the slot noise generator provides an excellent means of predicting the relative performance of receivers relative to strong-signal performance.

7.4 Tabular Results of Coverage

Table 13 - Large-market station Indoor population analysis

Callsign	Analog			IBOC		IBOC Tradeoffs			
	-Only	@1% IBOC	@10% IBOC	1% IBOC	10% IBOC				
	No Intf. Population	No Intf. Population	No Intf. Population	No Intf. Population	No Intf. Population	Baseline 1% IBOC vs. 1% Analog	1% IBOC vs. Analog	10% iboc VS. ANALOG	Analog @10% VS. ANALOG
KBPS-FM	1,699,430	1,699,430	1,561,848	718,493	1,456,720	42%	42%	86%	92%
KCPW-FM	909,629	714,220	342,726	229,316	770,264	32%	25%	85%	38%
KCSN	1,235,841	1,235,841	1,235,841	1,022,782	1,610,346	83%	83%	130%	100%
KCUR-FM	1,909,059	1,909,059	1,909,059	1,393,895	1,765,815	73%	73%	92%	100%
KETR	437,258	423,860	286,893	74,270	208,660	18%	17%	48%	66%
KKJZ	5,946,116	5,052,980	5,032,020	3,466,261	8,967,215	69%	58%	151%	85%
KNAA	19,396	19,396	19,396	4,297	15,338	22%	22%	79%	100%
KNOW-FM	3,208,493	3,208,493	3,201,317	2,297,623	3,014,644	72%	72%	94%	100%
KPRE	23,430	23,430	19,699	13,864	13,864	59%	59%	59%	84%
KPUB	73,196	70,662	70,662	54,215	62,859	77%	74%	86%	97%
KPVU	621,746	601,422	523,652	15,099	119,845	3%	2%	19%	84%
KROU	727,343	679,298	432,050	158,611	632,716	23%	22%	87%	59%
KSDS	1,328,955	1,305,871	999,477	300,669	941,500	23%	23%	71%	75%
KTXI	70,523	65,069	59,940	38,453	58,194	59%	55%	83%	85%
KUHF	4,709,286	4,709,286	4,709,286	3,382,710	4,709,819	72%	72%	100%	100%
KUNV	1,337,725	1,333,213	1,308,077	770,864	1,333,939	58%	58%	100%	98%
KUOW-FM	3,010,077	2,936,913	2,916,325	1,707,131	2,658,647	58%	57%	88%	97%
KVMR	87,723	75,776	54,325	21,597	70,765	29%	25%	81%	62%
KZYX	21,797	20,498	20,498	9,669	12,218	47%	44%	56%	94%
WBEZ	7,494,501	7,494,501	7,198,702	2,615,293	5,513,851	35%	35%	74%	96%
WBGO	9,730,199	8,822,903	4,341,967	1,026,604	5,640,227	12%	11%	58%	45%
WBSW	128,167	88,390	54,677	59,021	59,021	67%	46%	46%	43%
WBUR-FM	3,908,065	3,905,733	3,472,647	1,312,563	3,054,432	34%	34%	78%	89%
WCBE	1,395,365	1,358,616	1,288,967	778,796	1,277,546	57%	56%	92%	92%
WCBN-FM	102,380	89,889	75,095	44,029	118,077	49%	43%	115%	73%
WCPN	2,462,921	2,462,921	2,314,129	1,339,587	2,213,494	54%	54%	90%	94%
WDAV	1,929,836	1,784,751	1,311,448	631,112	1,572,152	35%	33%	81%	68%
WDCB	5,016,433	4,783,236	1,849,005	338,465	2,124,397	7%	7%	42%	37%
WDNA	1,412,255	1,412,255	1,412,255	95,506	853,971	7%	7%	60%	100%
WDUQ	1,738,971	1,719,303	1,666,319	778,327	1,443,394	45%	45%	83%	96%
WEAA	1,940,124	1,940,124	1,881,888	938,819	1,665,796	48%	48%	86%	97%
WFDD	1,494,490	1,432,532	1,132,538	463,069	1,145,145	32%	31%	77%	76%
WHUS	193,444	185,240	151,875	28,557	123,396	15%	15%	64%	79%
WJCT-FM	1,219,854	1,219,314	1,192,805	947,907	1,168,764	78%	78%	96%	98%
WMRY	30,180	30,180	23,481	17,028	30,114	56%	56%	100%	78%
WNAN	16,646	13,783	13,783	6,997	63,333	51%	42%	380%	83%
WNCU	489,679	438,736	342,942	196,588	469,676	45%	40%	96%	70%
WNJN-FM	207,870	165,136	59,010	19,205	222,344	12%	9%	107%	28%
WPLN-FM	1,522,021	1,522,021	1,494,613	763,420	1,338,971	50%	50%	88%	98%
WSIE	1,564,722	1,489,263	1,007,273	213,159	1,138,931	14%	14%	73%	64%
WUCF-FM	1,325,296	1,089,829	511,635	224,460	921,403	21%	17%	70%	39%
WUFT-FM	670,657	666,100	559,092	253,077	505,877	38%	38%	75%	83%
WUGA	173,516	154,585	80,960	25,432	121,159	16%	15%	70%	47%
WUMB-FM	510,184	488,005	257,356	96,947	480,652	20%	19%	94%	50%
WURC	15,513	15,513	15,513	8,240	14,213	53%	53%	92%	100%
WURI	30,530	28,989	26,480	16,803	27,389	58%	55%	90%	87%
WVXW	46,637	38,981	28,312	3,380	14,290	9%	7%	31%	61%
WXEL	2,567,591	2,470,177	1,750,476	685,015	1,674,937	28%	27%	65%	68%
WYMS	1,116,016	1,105,253	995,911	322,784	891,359	29%	29%	80%	89%
AVERAGE						**42%**	**39%**	**88%**	**80%**

Table 14 - Large-market station Mobile population analysis

Callsign	Analog -Only	Analog @1% IBOC	Analog @10% IBOC	IBOC 1% IBOC	IBOC 10% IBOC	IBOC Tradeoffs			
	No Intf. Population	No Intf. Population	No Intf. Population	No Intf. Population	No Intf. Population	Baseline 1% IBOC vs. 1% Analog	1% IBOC vs. Analog	10% iboc VS. ANALOG	Analog @10% VS. ANALOG
KBPS-FM	2,092,060	1,892,009	1,732,417	1,752,288	2,040,132	92.6%	83.8%	97.5%	82.8%
KCPW-FM	1,272,099	796,090	451,739	945,717	1,302,420	118.8%	74.3%	102.4%	35.5%
KCSN	1,423,640	1,408,643	1,408,643	1,935,614	2,953,664	137.4%	136.0%	207.5%	98.9%
KCUR-FM	2,138,655	2,138,655	2,125,085	1,938,016	2,173,102	90.6%	90.6%	101.6%	99.4%
KETR	997,346	835,841	593,303	387,449	1,315,642	46.4%	38.8%	131.9%	59.5%
KKJZ	7,344,228	5,866,913	5,736,900	10,624,986	12,781,660	181.1%	144.7%	174.0%	78.1%
KNAA	39,872	39,872	39,872	18,059	40,734	45.3%	45.3%	102.2%	100.0%
KNOW-FM	3,414,012	3,388,763	3,366,868	3,185,415	3,467,766	94.0%	93.3%	101.6%	98.6%
KPRE	31,745	31,745	30,531	22,062	22,062	69.5%	69.5%	69.5%	96.2%
KPUB	129,415	126,585	118,564	83,642	133,523	66.1%	64.6%	103.2%	91.6%
KPVU	882,111	868,425	855,966	636,430	1,484,958	73.3%	72.1%	168.3%	97.0%
KROU	932,285	730,873	516,121	734,725	909,423	100.5%	78.8%	97.5%	55.4%
KSDS	1,816,656	1,679,034	1,381,541	1,276,760	1,914,953	76.0%	70.3%	105.4%	76.0%
KTXI	81,711	74,255	71,130	74,806	107,937	100.7%	91.5%	132.1%	87.1%
KUHF	4,892,673	4,885,925	4,847,580	4,757,258	4,921,648	97.4%	97.2%	100.6%	99.1%
KUNV	1,348,676	1,348,676	1,340,324	1,331,681	1,360,133	98.7%	98.7%	100.8%	99.4%
KUOW-FM	3,421,671	3,311,603	3,276,672	3,188,738	3,636,160	96.3%	93.2%	106.3%	95.8%
KVMR	170,818	127,187	90,807	105,984	356,963	83.3%	62.0%	209.0%	53.2%
KZYX	76,425	71,146	65,751	23,321	86,139	32.8%	30.5%	112.7%	86.0%
WBEZ	9,041,448	8,610,156	8,059,197	7,310,790	8,967,299	84.9%	80.9%	99.2%	89.1%
WBGO	12,671,630	10,209,148	6,331,549	8,760,431	13,769,107	85.8%	69.1%	108.7%	50.0%
WBSW	238,399	120,472	74,244	275,129	275,129	228.4%	115.4%	115.4%	31.1%
WBUR-FM	5,239,926	4,737,233	4,300,381	4,087,751	5,797,974	86.3%	78.0%	110.6%	82.1%
WCBE	1,545,288	1,476,943	1,423,657	1,394,444	1,618,844	94.4%	90.2%	104.8%	92.1%
WCBN-FM	102,380	91,312	87,928	148,647	387,650	162.8%	145.2%	378.6%	85.9%
WCPN	3,160,479	2,919,367	2,623,346	2,598,217	3,271,588	89.0%	82.2%	103.5%	83.0%
WDAV	2,488,794	2,095,400	1,671,225	1,981,666	2,687,507	94.6%	79.6%	108.0%	67.1%
WDCB	7,447,421	5,785,075	3,097,636	5,375,411	7,458,308	92.9%	72.2%	100.1%	41.6%
WDNA	1,720,052	1,720,052	1,720,052	1,294,072	2,741,310	75.2%	75.2%	159.4%	100.0%
WDUQ	2,309,311	2,225,965	2,087,927	1,836,026	2,467,980	82.5%	79.5%	106.9%	90.4%
WEAA	2,364,815	2,364,815	2,316,856	2,082,545	3,092,291	88.1%	88.1%	130.8%	98.0%
WFDD	2,380,865	1,879,286	1,413,319	1,511,180	2,435,274	80.4%	63.5%	102.3%	59.4%
WHUS	375,887	344,673	300,041	236,848	1,001,642	68.7%	63.0%	266.5%	79.8%
WJCT-FM	1,340,384	1,310,899	1,259,641	1,228,008	1,392,908	93.7%	91.6%	103.9%	94.0%
WMRY	99,257	64,837	44,599	34,083	144,706	52.6%	34.3%	145.8%	44.9%
WNAN	25,015	18,390	18,390	101,664	198,236	552.8%	406.4%	792.5%	73.5%
WNCU	584,902	499,629	400,425	674,795	1,152,331	135.1%	115.4%	197.0%	68.5%
WNJN-FM	209,438	165,136	85,039	237,189	455,522	143.6%	113.3%	217.5%	40.6%
WPLN-FM	1,814,599	1,704,066	1,626,210	1,532,817	1,819,906	90.0%	84.5%	100.3%	89.6%
WSIE	2,333,868	2,010,290	1,455,292	1,590,593	2,357,488	79.1%	68.2%	101.0%	62.4%
WUCF-FM	1,407,004	1,112,464	687,444	1,287,467	1,802,106	115.7%	91.5%	128.1%	48.9%
WUFT-FM	1,086,263	851,654	725,985	688,410	1,073,779	80.8%	63.4%	98.9%	66.8%
WUGA	271,474	185,623	135,281	190,906	374,143	102.8%	70.3%	137.8%	49.8%
WUMB-FM	616,046	539,680	332,217	860,153	2,021,789	159.4%	139.6%	328.2%	53.9%
WURC	36,836	21,162	16,789	33,826	261,882	159.8%	91.8%	710.9%	45.6%
WURI	46,235	33,329	27,389	31,412	38,021	94.2%	67.9%	82.2%	59.2%
WVXW	93,558	74,742	60,947	43,563	104,417	58.3%	46.6%	111.6%	65.1%
WXEL	3,604,519	2,471,954	2,029,662	2,423,218	3,158,860	98.0%	67.2%	87.6%	56.3%
WYMS	1,426,813	1,302,283	1,123,218	1,112,423	1,640,277	85.4%	78.0%	115.0%	78.7%
Average						**106.7%**	**88.8%**	**162.0%**	**75.8%**

Table 15 - Large-market station Portable population analysis

Callsign	Analog			IBOC		IBOC Tradeoffs			
	-Only	@1% IBOC	@10% IBOC	1% IBOC	10% IBOC				
	No Intf. Population	No Intf. Population	No Intf. Population	No Intf. Population	No Intf. Population	Baseline 1% IBOC vs. 1% Analog	1% IBOC vs. Analog	10% iboc VS. ANALOG	Analog @10% VS. ANALOG
KBPS-FM	1,221,741	1,221,741	1,221,741	457,504	953,282	37.4%	37.4%	78.0%	100.0%
KCPW-FM	538,649	538,649	538,649	136,321	435,425	25.3%	25.3%	80.8%	100.0%
KCSN	1,241,212	1,065,452	1,065,452	998,815	1,100,790	93.7%	80.5%	88.7%	85.8%
KCUR-FM	1,698,825	1,695,158	1,695,158	863,126	1,603,897	50.9%	50.8%	94.4%	99.8%
KETR	134,756	134,756	131,601	26,524	111,355	19.7%	19.7%	82.6%	97.7%
KKJZ	7,604,427	4,389,568	4,389,568	1,252,044	6,125,979	28.5%	16.5%	80.6%	57.7%
KNAA	11,259	11,259	11,259	433	8,877	3.8%	3.8%	78.8%	100.0%
KNOW-FM	2,908,859	2,904,139	2,903,005	1,565,493	2,698,560	53.9%	53.8%	92.8%	99.8%
KPRE	9,093	9,093	9,093	13,864	13,864	152.5%	152.5%	152.5%	100.0%
KPUB	59,427	59,427	59,427	47,001	54,032	79.1%	79.1%	90.9%	100.0%
KPVU	43,611	43,611	43,611	6,660	26,297	15.3%	15.3%	60.3%	100.0%
KROU	476,458	450,393	450,393	49,287	303,390	10.9%	10.3%	63.7%	94.5%
KSDS	730,348	672,764	608,561	83,569	517,248	12.4%	11.4%	70.8%	83.3%
KTXI	55,271	53,764	51,441	13,790	50,073	25.6%	24.9%	90.6%	93.1%
KUHF	4,546,902	4,546,902	4,546,902	1,660,632	4,192,226	36.5%	36.5%	92.2%	100.0%
KUNV	1,296,351	1,296,351	1,296,351	377,420	1,189,372	29.1%	29.1%	91.7%	100.0%
KUOW-FM	2,386,731	2,304,551	2,304,551	1,118,531	2,035,477	49%	47%	85%	97%
KVMR	38,933	38,933	38,933	9,971	38,969	26%	26%	100%	100%
KZYX	10,726	10,726	10,726	5,811	7,679	54%	54%	72%	100%
WBEZ	4,279,224	4,279,224	4,279,224	1,207,419	3,639,352	28%	28%	85%	100%
WBGO	3,335,243	3,180,778	2,893,069	454,623	1,832,273	14%	14%	55%	87%
WBSW	35,522	29,734	29,734	12,943	12,943	44%	36%	36%	84%
WBUR-FM	2,363,026	2,353,415	2,338,972	373,494	1,897,244	16%	16%	80%	99%
WCBE	1,188,583	1,188,583	1,188,583	364,377	1,082,876	31%	31%	91%	100%
WCBN-FM	86,409	77,031	76,330	19,639	66,912	25%	23%	77%	88%
WCPN	1,931,656	1,931,656	1,931,656	677,163	1,766,985	35%	35%	91%	100%
WDAV	1,286,957	1,286,957	1,286,957	212,736	945,451	17%	17%	73%	100%
WDCB	1,192,407	1,192,407	1,023,701	121,673	690,866	10%	10%	58%	86%
WDNA	433,458	433,458	433,458	27,812	273,492	6%	6%	63%	100%
WDUQ	1,233,988	1,204,929	1,204,929	470,764	1,044,217	39%	38%	85%	98%
WEAA	1,500,350	1,488,980	1,488,980	477,459	1,253,168	32%	32%	84%	99%
WFDD	946,244	920,635	884,436	165,239	723,055	18%	17%	76%	93%
WHUS	89,454	89,454	89,454	19,901	71,927	22%	22%	80%	100%
WJCT-FM	1,142,976	1,142,976	1,142,976	795,542	1,087,126	70%	70%	95%	100%
WMRY	20,690	17,918	15,586	13,471	20,267	75%	65%	98%	75%
WNAN	9,382	9,382	9,382	3,501	8,706	37%	37%	93%	100%
WNCU	375,786	366,428	366,428	81,583	288,292	22%	22%	77%	98%
WNJN-FM	117,063	100,223	76,443	9,520	52,492	9%	8%	45%	65%
WPLN-FM	1,188,026	1,188,026	1,188,026	493,274	1,078,108	42%	42%	91%	100%
WSIE	846,175	770,975	752,816	81,756	440,159	11%	10%	52%	89%
WUCF-FM	599,966	595,420	595,420	79,200	367,577	13%	13%	61%	99%
WUFT-FM	439,649	439,649	429,335	190,466	370,049	43%	43%	84%	98%
WUGA	93,086	93,086	76,853	6,798	55,294	7%	7%	59%	83%
WUMB-FM	332,780	294,754	209,536	29,997	216,039	10%	9%	65%	63%
WURC	10,273	10,273	10,273	6,087	9,058	59%	59%	88%	100%
WURI	25,231	25,231	25,231	9,412	20,088	37%	37%	80%	100%
WVXW	11,000	11,000	11,000	3,380	7,307	31%	31%	66%	100%
WXEL	1,197,403	1,182,790	1,177,074	311,341	926,015	26%	26%	77%	98%
WYMS	717,904	717,904	717,904	160,569	537,445	22%	22%	75%	100%
Average						**35%**	**33%**	**81%**	**96%**

Table 16 - Coverage analysis of 22 public radio stations on Non-Reserved FM channels

		Analog			IBOC					
Callsign	Category	-Only Population Served	@1% IBOC Population Served	@10% IBOC Population Served	1% IBOC Population Served	10% IBOC Population Served	Baseline 1% IBOC vs. 1% Analog	1% IBOC vs. Analog	10% iboc VS. ANALOG	Analog @10% VS. ANALOG
KFUO	Indoor	2,705,818	2,704,556	2,684,282	2,036,141	2,547,107	75%	75%	94%	99%
KIBX	Indoor	8,360	8,360	8,360	10,220	10,549	122%	122%	126%	100%
KJJP	Indoor	233,141	233,141	233,141	189,059	217,296	81%	81%	93%	100%
KMTH	Indoor	156,214	156,214	156,214	5,393	143,228	3%	3%	92%	100%
KOOZ	Indoor	13,616	13,616	13,616	4,144	7,669	30%	30%	56%	100%
KOSN	Indoor	765,364	755,352	710,500	51,063	451,943	7%	7%	59%	93%
KOWI	Indoor	69,728	69,728	65,437	7,652	35,295	11%	11%	51%	94%
KROU	Indoor	727,343	679,298	432,050	158,611	632,716	23%	22%	87%	59%
KUOW	Indoor	3,010,077	2,936,913	2,916,325	1,707,131	2,658,647	58%	57%	88%	97%
KZSD	Indoor	13,583	13,583	13,583	2,240	8,437	16%	16%	62%	100%
WAMQ	Indoor	51,986	51,083	43,359	16,780	32,417	33%	32%	62%	83%
WBAA	Indoor	211,531	211,531	207,657	33,617	150,007	16%	16%	71%	98%
WBST	Indoor	260,327	193,033	106,125	66,144	486,962	34%	25%	187%	41%
WCAN	Indoor	91,562	89,875	75,242	14,739	180,453	16%	16%	197%	82%
WCMB	Indoor	84,986	84,986	84,986	9,051	65,214	11%	11%	77%	100%
WEXT	Indoor	164,584	149,176	97,247	34,367	76,039	23%	21%	46%	59%
WFIU	Indoor	541,403	526,613	425,301	121,587	266,939	23%	22%	49%	79%
WIRN	Indoor	70,229	70,229	70,229	33,130	60,393	47%	47%	86%	100%
WMEF	Indoor	6,651	6,651	6,651	4,233	5,092	64%	64%	77%	100%
WMRY	Indoor	35,827	31,124	23,481	17,028	30,114	55%	48%	84%	66%
WMUK	Indoor	972,434	944,301	817,719	262,384	646,695	28%	27%	67%	84%
WVGR	Indoor	1,515,979	1,493,370	1,416,182	407,836	1,248,506	27%	27%	82%	93%
AVERAGES							**37%**	**36%**	**86%**	**88%**
KFUO	Mobile	2,899,895	2,869,176	2,810,908	2,713,338	2,903,558	95%	94%	100%	97%
KIBX	Mobile	9,397	9,397	9,397	10,220	12,356	109%	109%	131%	100%
KJJP	Mobile	260,500	260,500	260,500	230,415	276,448	88%	88%	106%	100%
KMTH	Mobile	183,268	183,268	183,268	154,869	219,794	85%	85%	120%	100%
KOOZ	Mobile	29,717	28,264	28,264	16,241	38,255	57%	55%	129%	95%
KOSN	Mobile	1,183,805	1,121,196	1,021,542	768,159	1,336,201	69%	65%	113%	86%
KOWI	Mobile	133,295	129,060	118,572	66,008	152,052	51%	50%	114%	89%
KROU	Mobile	932,285	730,873	516,121	734,725	909,423	101%	79%	98%	55%
KUOW	Mobile	3,421,671	3,311,603	3,276,672	3,188,738	3,636,160	96%	93%	106%	96%
KZSD	Mobile	39,426	39,462	39,462	19,099	43,222	48%	48%	110%	100%
WAMQ	Mobile	155,187	106,680	87,640	53,350	225,445	50%	34%	145%	56%
WBAA	Mobile	326,581	306,582	291,956	210,316	338,366	69%	64%	104%	89%
WBST	Mobile	352,000	206,515	131,375	272,917	544,508	132%	78%	155%	37%
WCAN	Mobile	158,402	142,355	113,301	85,571	380,467	60%	54%	240%	72%
WCMB	Mobile	133,172	133,172	130,157	81,774	140,400	61%	61%	105%	98%
WEXT	Mobile	519,049	232,867	148,695	145,573	483,987	63%	28%	93%	29%
WFIU	Mobile	1,091,831	978,374	768,874	586,151	1,359,303	60%	54%	124%	70%
WIRN	Mobile	102,594	102,594	101,022	76,719	122,221	75%	75%	119%	98%
WMEF	Mobile	13,056	13,056	13,056	5,959	13,576	46%	46%	104%	100%
WMRY	Mobile	99,257	64,837	44,599	34,083	144,706	53%	34%	146%	45%
WMUK	Mobile	1,616,691	1,408,929	1,151,357	1,022,335	1,578,020	73%	63%	98%	71%
WVGR	Mobile	1,997,280	1,817,719	1,679,745	1,531,781	1,991,811	84%	77%	100%	84%
AVERAGES							**74%**	**65%**	**121%**	**80%**
KFUO	Portable	2,446,944	2,446,944	2,446,944	1,345,851	2,281,614	55%	55%	93%	100%
KIBX	Portable	7,560	7,560	7,560	6,638	10,549	88%	88%	140%	100%
KJJP	Portable	204,954	204,954	204,954	114,529	200,403	56%	56%	98%	100%
KMTH	Portable	87,558	87,558	87,558	816	816	1%	1%	1%	100%
KOOZ	Portable	6,788	6,778	6,778	4,144	4,144	61%	61%	61%	100%
KOSN	Portable	332,622	332,622	332,622	9,528	175,065	3%	3%	53%	100%
KOWI	Portable	29,423	28,423	28,423	4,344	16,091	15%	15%	55%	97%
KROU	Portable	476,458	450,393	410,960	49,287	303,390	11%	10%	64%	86%
KUOW	Portable	2,386,731	2,304,551	2,306,570	1,118,531	2,035,477	49%	47%	85%	97%
KZSD	Portable	8,629	8,629	8,629	382	4,881	4%	4%	57%	100%
WAMQ	Portable	26,008	25,105	25,105	15,273	23,046	61%	59%	89%	97%
WBAA	Portable	125,483	125,438	125,438	5,239	78,747	4%	4%	63%	100%
WBST	Portable	112,727	107,947	102,328	26,497	328,814	25%	24%	292%	91%
WCAN	Portable	30,279	30,279	29,526	26,497	97,452	88%	88%	322%	98%
WCMB	Portable	38,481	38,481	38,481	3,222	17,230	8%	8%	45%	100%
WEXT	Portable	61,165	58,043	55,179	13,769	43,392	24%	23%	71%	90%
WFIU	Portable	192,225	192,225	192,225	94,938	159,243	49%	49%	83%	100%
WIRN	Portable	51,991	51,991	51,991	9,065	45,868	17%	17%	88%	100%
WMEF	Portable	5,959	5,959	5,959	3,350	5,092	56%	56%	85%	100%
WMRY	Portable	20,690	17,918	15,586	13,471	20,267	75%	65%	98%	75%
WMUK	Portable	490,897	490,897	484,761	99,506	406,744	20%	20%	83%	99%
WVGR	Portable	1,057,929	1,057,929	1,057,929	59,602	772,488	6%	6%	73%	100%
AVERAGES							**35%**	**34%**	**95%**	**97%**

7.5 Maps of the 50 Larger Market and 25 Smaller Market Stations

Maps of the 75 stations used for the impact analyses were provided to CPB as graphic image files on a CD-ROM on April 2, 2008 with the semi-final version this document.

7.6 Previous Reports delivered to CPB

The following sections are copies of previous reports supplied to CPB during the DRCIA project. Additional project narrative reports were submitted in June and August, 2007, and February, 2008 – the contents of those reports are incorporated into this Final Report.

DRCIA Reports	Date submitted to CPB
Interim report #1 - Station selections for market study and field measurements, with communications plan; covered 11/1/06 – 12/31/06 .	1/9/07
Interim report #2 - update on station selections plus RF test bed; covered 11/1/06 – 1/31/07	3/29/07
IBOC Receiver Report	7/10/07
Analog Receiver Report	7/23/07
Station Field Measurement Report	7/25/07
Single Frequency Networks (SFN) Report	1/22/08
Receiver Improvements Report	1/25/08
Urban Noise Effects Report	1/31/08
Indoor Antenna Test Report	2/20/08
Final narrative report – covering the final months of the project	5/16/08
Communications Plan – updated May 15, 2008	5/15/08

NATIONAL PUBLIC RADIO

Report to the Corporation for Public Broadcasting

Digital Radio Coverage & Interference Analysis (DRCIA) Project:
Station Selections for Market Study and Field Measurements, and
Project Communications Plan
Deliverables 2.1, 2.2 and 2.3

CPB Account No. 10446
Reporting Period: November 1, 2006 through December 31, 2006

INTRODUCTION

National Public Radio appreciates CPB's leadership in launching the Digital Radio Coverage and Interference Analysis (DRCIA) Project, an important initiative to maximize the reach of new digital public radio services to all Americans, not just those in urban areas. This is NPR's first report on the project, spanning November 1, 2006 through December 31, 2006. These materials focus on NPR's selection of stations needed for market studies, as stated in Deliverable 2.2 of the contract and in Section A(i) of the DRCIA *Scope of Work*:

> "…quantify the analog coverage and future digital coverage for actual public radio stations in fifty (50) of the largest public radio markets and twenty five (25) smaller public radio markets. This will be accomplished through individual analysis of the identified markets and will consider the potential economic impact of reduced listener membership and market share-related earnings resulting from differences between current analog and hybrid IBOC DAB service."

As discussed further below and in CPB's RFP and NPR's proposal, we plan to study markets where significant service is provided by public radio stations located outside or at the periphery of the markets, where field strength of these transmitters is above 50 dBuV and at or below 66 dBuV.

This report also includes a draft list of the ten (10) stations proposed to be used in the development of the NPR Predictive Model (deliverable 2.3), a detailed discussion of our method for developing this list, and the next steps to finalization. In addition, our Project Communications Plan (deliverable 2.1) is enclosed as a separate document.

SELECTION TECHNIQUE FOR STATIONS IN LARGEST RADIO MARKETS

The contract refers to a "radio market" but does not define it or specify the number of stations to be studied in each radio market. NPR has utilized the 299 radio markets established by Arbitron Inc. to demarcate the geographic areas and populations in this study. The Arbitron markets (hereafter "markets) are listed in Appendix A.

As CPB is aware, it is NPR's intention to generate analog and HD Radio coverage predictions of all CPB-qualified FM stations in the system, numbering more than 860. In addition to providing the resulting data on individual stations, we will roll up the data to delineate coverage numbers for analog vs. digital across the top 50 markets, as well as on statewide and national bases. This aggregation of data will provide the total market impact information that CPB desires.

There are a total of 256 CPB-qualified stations in the 50 largest markets, with a few markets containing a dozen or more public radio stations. A list of these stations is attached as Appendix B. These will be used to project the effects of HD Radio coverage and signal extension techniques in smaller markets.

SELECTION TECHNIQUE FOR 25 SMALLER MARKETS

As noted above, the RFP language for "twenty-five smaller markets" addresses the disenfranchisement potential for stations with peripheral audience coverage, such as cases where communities of significant size lie just outside the reliable IBOC DAB coverage, but within the usable coverage of the analog FM host. We expect stations with a substantial audience located geographically at the periphery of analog FM coverage to be more affected by IBOC DAB coverage shortfall than stations that serve dispersed suburbs or rural areas in the outlying coverage area. As a result, they may have a greater need for service expansion techniques to fill in missing IBOC DAB coverage in those audience concentrations.

We believe that this is a coverage issue that warrants attention in the study. Accordingly, we interpret our contract responsibility relative to the 25 markets to mean selection of stations that serve a significant peripheral audience with analog FM service while not adequately covering this audience with IBOC DAB service. (Coverage will be determined from a prediction model developed for the project, based on laboratory measurements of consumer receivers and field verifications.) Since these stations represent a special case, they will not be used to project market coverage results in general to the overall group of public radio stations. However, they are illustrative of important cases and a basis for exploring the potential effectiveness of IBOC coverage fill-in techniques.

To prepare this list (Table 1 below), we examined the FCC contour coverage of all stations in markets ranked 51 through 299, and selected stations that show towns or cities of significant size in the area between the 50 dBu and 66 dBu contours. Maps showing the selected stations' coverage are included with this document as Appendix C.

Table 1 - Stations selected from 25 smaller markets with peripheral audience coverage.

Call Sign	City, State	Arbitron Market
WJWV	Ft. Gaines, GA	193
WUNC	Chapel Hill, NC	128
WUCX	Bay City, MI	125
WFFC	Ferrum, VA	116
WQPR	Muscle Shoals, AL	115
WEVO	Concord, NH	114
WMEA	Portland, ME	114
WBST	Muncie, IN	105
WEKF	Corbin, KY	104
KSUI	Iowa City, IA	91
KLRE	Little Rock, AR	85
KAZU	Santa Cruz, CA	79
KBDH	San Ardo, CA	79
KMTH	Maljamar, NM	70
KSJV	Fresno, CA	66
KHPR	Honolulu, HI	63
WCAN	Canajohari, NY	61
KHID	McAllen TX	59
WDPR	Dayton, OH	58
WVSU	Birmingham, AL	56
WGMC	Rochester, MN	53
WNJN	Atlantic City, NJ	51
WBJC	Baltimore, MD	21
KRUA	Anchorage, AK	171
KUNR	Reno, NV	124

SELECTION OF STATIONS FOR FIELD MEASUREMENT

We plan to perform field measurements of IBOC DAB and analog FM coverage in early 2007 to validate our coverage prediction model, which we developed in parts over the past two years. This aspect of the DRCIA project addresses interference parts of the model. The candidates for measurement are 205 CPB-qualified public radio stations currently operating in HD Radio (hybrid IBOC DAB mode). Of these, at least 10 stations will be selected for characteristics that will test and help fine-tune the coverage prediction model.

The coverage prediction model will consider interference-limited coverage separately for analog and digital service and is based on NPR Labs' laboratory measurements of consumer radio performance, performed under this contract project, combined with industry-recognized algorithms for signal propagation. Since the IBOC DAB prediction model must consider channel interference, we intend to select real station coverage conditions that will test and validate the algorithms and ratios we will determine in the laboratory.

Examples of interference ratios are listed in Table 2 (for hybrid-to-hybrid IBOC DAB interference), which were derived from measurements previously conducted for the

National Radio Systems Committee. This table shows that cochannel situations with multipath (mobile) fading requires the desired channel IBOC signal to be at least 6 dB above the strength of the undesired IBOC signal to maintain a 10% block error rate, which is assumed to provide artifact-free digital reception. For a single first-adjacent channel interferer alone, the desired IBOC signal may be at least 14 dB below the undesired IBOC signal, but when first-adjacent signals occur on both sides of the desired channel the desired signal must be as much as 41 dB above the two undesired signals. Other combinations of first- and second-adjacent channel interferers are also listed. These complex relationships will appear in the prediction algorithm used for coverage, but must be tested with field conditions that attempt to replicate the ratios derived in the laboratory.

Table 2 – Minimum Hybrid D/U Ratios For 10% BLER With Medium (-62 dBm) Desired Signal

Interfering Channel Relationship	Fixed Signal Scenarios (dB)	Multipath Scenarios (dB)
Cochannel	2	4 to 6
Single-1st Adjacent	-32	-14 to -18
Dual-1st Adjacent	18	28 to 41
Single-2nd Adjacent	<-42*	-45 to 45.5
Dual-2nd Adjacent	<-42*	-43.5 to -44.5
Single-1st & Single-2nd Adjacent	<-42*	-12 to -34

* Test bed was limited to undesired signal of 0 dBm

We began a manual search for station measurement candidates but the complexities of testing hundreds of HD Radio stations against more than a thousand potentially-interfering stations made computer analysis necessary. We engaged the consulting engineering firm of Hammett & Edison to develop a computer program to evaluate all 205 public radio stations currently broadcasting in IBOC DAB, using terrain-sensitive coverage analysis with the newly-derived ratio thresholds to predict the total area of potential interference for each station. (Hammett & Edison, with whom NPR worked extensively as part of the Tomorrow Radio Project, is also being contracted for other aspects of this DRCIA project.) To minimize cost, this study was performed mathematically and no maps were generated.

The computer study grouped stations according to various interference combinations and within these groups the stations were ranked according to land areas and interference population. We then examined the listings to determine the best candidates for measurement, as shown in Table 3. A minimum of 10 stations were selected across the country to evaluate various interference and coverage scenarios. We considered cases of analog-to-hybrid interference as well the effects of urban noise on IBOC DAB coverage. Portions of the coverage areas of the desired channel stations may provide multiple measurement objectives, such as single 2nd-adjacent channel interference in one area and interference-free (noise limited) coverage in areas remote from the interference. Later in the study, this data will be separated for processing and validation.

Table 3 - Draft list of stations selected for field measurement (subject to revision after completion of computer processing of the comprehensive data list).

Interference Case	Station	City, State	Service area, km^2	Interference area, km^2	Percent Interference
Dual first adjacent, both digital	WFUV	New York, NY	7,201	1,339	18.6%
Dual first adjacent, one digital, one analog	KQEI	North Highlands, CA	3,503	3,363	96.0%
	WUSF	Tampa, FL	15,982	2,820	17.6%
	WNYC	New York, NY	8,385	2,354	28.1%
	WXPN	Philadelphia, PA	10,648	2,933	27.5%
	KANV	Olsburg, KS	5,677	2,894	51.0%
	KPCC	Pasadena, CA	5,215	1,680	32.2%
Dual first adjacent, both analog	KXPR	Sacramento, CA	19,687	14,897	75.7%
	WDAV	Davidson, NC	20,274	9,224	45.5%
	KALW	San Francisco, CA	2,202	1,823	82.8%

Maps showing the analog service and interference contours for the above stations are included as Appendix D. These show the F(50,50) 60 dBu contours in green for the candidate test stations, the co-channel F(50,10) 40 dBu contours in orange, the first-adjacent channel F(50,50) 54 dBu contours in red and the second-adjacent channel F(50,10) 80 dBu contours in brown. These contours are only for general reference and do no depict the service and interference conditions for IBOC DAB.

A second map is shown for WUSF, Tampa, Florida, to illustrate the relationship of interference arising from two adjacent channel stations. WKSG operates on 89.5 MHz, 200 kHz below WUSF, and WUCF operates on 89.9 MHz, 200 kHz above WUSF. The analog sideband emissions of these two stations can overlap the digital carriers of WUSF, which extend from approximately 120 to 198 kHz above and below the channel center. If interference occurs from both adjacent channel stations at the same receiving location, WUSF's IBOC transmission will be seriously impaired. (Note in Table 2 that the interference threshold D/U ratio drops from approximately -14 to -18 dB with one carrier to 28 to 41 dB with two carriers.) Although the software tools have not yet been developed to predict this dual-interference condition, an Irregular Terrain Model (ITM) prediction has been modified to show locations where signals from both adjacent stations are above 20 dBu, which appears as a pink area to the northeast of WUSF. If the field strength of WUSF were 60 dBu, a D/U ratio of less than 40 dB from both stations would exist at these locations, resulting in potential interference to the IBOC transmission. By comparison, the FCC's required D/U ratio of analog FM protection is 20 dB, thus these ratio conditions are permissible and quite possible.

It should be noted that our laboratory measurements of receivers, to be conducted in early 2007 will yield more accurate interference ratios than those compiled from NRSC data in Table 2. Accordingly, we intend to review our initial selections in light of any new data, before committing to actual field measurements. We will fully inform CPB regarding any changes in the selectees for field measurement as well as the addition of stations, if needed, to provide a sound statistical basis for the prediction model.

Appendix A - ARBITRON RADIO MARKETS

Market Rank	Market Name	Metro 12+ Population
1	New York, NY	15,291100
2	Los Angeles, CA	10,826,600
3	Chicago, IL	7,738,000
4	San Francisco, CA	5,891,900
5	Dallas-Ft. Worth, TX	4,838,600
6	Houston-Galveston, TX	4,469,900
7	Philadelphia, PA	4,360,200
8	Washington, DC	4,176,300
9	Atlanta, GA	4,085,000
10	Detroit, MI	3,888,300
11	Boston, MA	3,838,800
12	Miami-Ft. Lauderdale-Hollywood, FL	3,533,000
13	Puerto Rico	3,296,800
14	Seattle-Tacoma, WA	3,257,200
15	Phoenix, AZ	3,058,000
16	Minneapolis-St. Paul, MN	2,662,100
17	San Diego, CA	2,497,000
18	Nassau-Suffolk (Long Island), NY	2,373,900
19	Tampa-St. Petersburg-Clearwater, FL	2,314,300
20	St. Louis, MO	2,282,700
21	Baltimore, MD	2,257,900
22	Denver-Boulder, CO	2,194,800
23	Portland, OR	2,001,600
24	Pittsburgh, PA	1,998,800
25	Riverside-San Bernardino, CA	1,806,800
26	Cleveland, OH	1,794,200
27	Sacramento, CA	1,785,400
28	Cincinnati, OH	1,721,200
29	San Antonio, TX	1,586,000
30	Kansas City, MO-KS	1,575,300
31	Salt Lake City-Ogden-Provo, UT	1,554,200
32	Las Vegas, NV	1,484,400
33	Charlotte-Gastonia-Rock Hill, NC-SC	1,456,600
34	Orlando, FL	1,448,600
35	San Jose, CA	1,436,400
36	Milwaukee-Racine, WI	1,433,300
37	Columbus, OH	1,422,700
38	Providence-Warwick-Pawtucket, RI	1,393,500
39	Middlesex-Somerset-Union, NJ	1,382,800
40	Indianapolis, IN	1,328,100
41	Norfolk-Virginia Beach-Newport News, VA	1,327,600
42	Austin, TX	1,252,400
43	Raleigh-Durham, NC	1,184,200
44	Nashville, TN	1,158,800
45	Greensboro-Winston-Salem-High Point, NC	1,131,200
46	West Palm Beach-Boca Raton, FL	1,116,800
47	Jacksonville, FL	1,083,700
48	Oklahoma City, OK	1,075,700
49	Memphis, TN	1,060,700
50	Hartford-New Britain-Middletown, CT	1,047,700
51	Monmouth-Ocean, NJ	1,020,500
52	Buffalo-Niagara Falls, NY	979,600
53	Rochester, NY	936,000
54	Louisville, KY	930,600
55	Richmond, VA	916,400
56	Birmingham, AL	875,300
57	New Orleans, LA	864,100
58	McAllen-Brownsville-Harlingen, TX	838,400
59	Dayton, OH	835,500
60	Greenville-Spartanburg, SC	824,900
61	Tucson, AZ	803,300
62	Ft. Myers-Naples-Marco Island, FL	783,100

Appendix A - ARBITRON RADIO MARKETS

63	Albany-Schenectady-Troy, NY	778,800
64	Honolulu, HI	768,300
65	Tulsa, OK	732,000
66	Fresno, CA	723,400
67	Grand Rapids, MI	708,400
68	Allentown-Bethlehem, PA	690,600
69	Wilkes Barre-Scranton, PA	684,200
70	Albuquerque, NM	672,000
71	Knoxville, TN	644,100
72	Omaha-Council Bluffs, NE-IA	617,600
73	Sarasota-Bradenton, FL	610,100
74	Akron, OH	599,000
75	Wilmington, DE	590,300
76	El Paso, TX	580,900
77	Baton Rouge, LA	568,700
78	Bakersfield, CA	567,800
79	Harrisburg-Lebanon-Carlisle, PA	560,800
80	Monterey-Salinas-Santa Cruz, CA	556,200
81	Stockton, CA	555,500
82	Syracuse, NY	555,100
83	Gainesville-Ocala, FL	530,600
84	Springfield, MA	529,500
85	Little Rock, AR	523,200
86	Daytona Beach, FL	518,500
87	Toledo, OH	517,200
88	Charleston, SC	511,500
89	Greenville-New Bern-Jacksonville, NC	504,900
90	Mobile, AL	501,300
91	Columbia, SC	494,600
92	Des Moines, IA	493,600
93	Spokane, WA	491,800
94	Melbourne-Titusville-Cocoa, FL	476,400
95	Madison, WI	468,800
96	Lakeland-Winter Haven, FL	468,500
97	Colorado Springs, CO	467,900
98	Wichita, KS	466,700
99	Ft. Pierce-Stuart-Vero Beach, FL	465,700
100	Visalia-Tulare-Hanford, CA	455,700
101	Johnson City-Kingsport-Bristol, TN-VA	455,600
102	Lafayette, LA	447,200
103	York, PA	445,500
104	Lexington-Fayette, KY	440,200
105	Boise, ID	435,100
106	Ft. Wayne, IN	429,100
107	Chattanooga, TN	423,600
108	Modesto, CA	421,800
109	Augusta, GA	419,200
109	New Haven, CT	419,200
111	Worcester, MA	417,100
112	Morristown, NJ	416,500
113	Huntsville, AL	415,900
114	Lancaster, PA	413,500
115	Roanoke-Lynchburg, VA	412,300
116	Portsmouth-Dover-Rochester, NH	412,200
117	Youngstown-Warren, OH	407,200
118	Jackson, MS	405,500
119	Santa Rosa, CA	403,400
120	Oxnard-Ventura, CA	402,600
121	Bridgeport, CT	395,900
122	Lansing-East Lansing, MI	389,400
123	Reno, NV	384,900
124	Ft. Collins-Greeley, CO	379,800
124	Pensacola, FL	379,800

Appendix A - ARBITRON RADIO MARKETS

126	Victor Valley, CA	376,600
127	Flint, MI	369,400
128	Canton, OH	350,100
129	Fayetteville, NC	348,800
130	Reading, PA	342,800
131	Saginaw-Bay City-Midland, MI	339,200
132	Shreveport, LA	336,200
133	Beaumont-Port Arthur, TX	324,500
134	Appleton-Oshkosh, WI	323,300
135	Fayetteville (North West Arkansas), AR	319,100
136	Corpus Christi, TX	319,000
137	Palm Springs, CA	318,800
138	Burlington-Plattsburgh, VT-NY	317,200
139	Atlantic City-Cape May, NJ	317,100
140	Newburgh-Middletown (Mid Hudson Valley), NY	314,800
141	Trenton, NJ	312,600
142	Springfield, MO	307,500
143	Quad Cities (Davenport-Rock Island-Moline), IA-IL	304,300
144	Biloxi-Gulfport-Pascagoula, MS	303,400
145	Salisbury-Ocean City, MD	302,000
145	Stamford-Norwalk, CT	302,000
147	Ann Arbor, MI	297,100
148	Tyler-Longview, TX	296,800
149	Peoria, IL	295,800
150	Eugene-Springfield, OR	294,800
151	Flagstaff-Prescott, AZ	290,700
151	Montgomery, AL	290,700
153	Fredericksburg, VA	288,400
154	Rockford, IL	287,300
155	Macon, GA	280,100
156	Killeen-Temple, TX	273,100
157	Huntington-Ashland, WV-KY	270,300
158	Savannah, GA	265,300
159	Asheville, NC	258,800
160	Utica-Rome, NY	257,600
161	Myrtle Beach, SC	257,200
162	Evansville, IN	257,100
163	Poughkeepsie, NY	255,100
164	Tallahassee, FL	253,300
165	Hagerstown-Chambersburg-Waynesboro, MD-PA	243,600
166	Wilmington, NC	241,800
167	Portland, ME	240,600
168	Erie, PA	238,000
169	Concord (Lake Regions), NH	236,400
170	Wausau-Stevens Point, (Central Wisconsin), WI	236,000
171	Anchorage, AK	229,700
172	San Luis Obispo, CA	229,500
173	New London, CT	228,600
174	Lincoln, NE	227,700
175	Morgantown-Clarksburg-Fairmont, WV	224,700
176	Ft. Smith, AR	224,600
177	New Bedford-Fall River, MA	222,600
178	South Bend, IN	220,500
179	Lebanon-Rutland-White River Junction, NH-VT	215,900
180	Merced, CA	214,500
181	Binghamton, NY	214,200
182	Charleston, WV	213,000
183	Lubbock, TX	211,600
184	Kalamazoo, MI	204,500
185	Green Bay, WI	203,500
186	Columbus, GA	203,000

Appendix A - ARBITRON RADIO MARKETS

187	Odessa-Midland, TX	202,600
188	Tupelo, MS	201,500
189	Cape Cod, MA	201,000
190	Manchester, NH	198,700
191	Johnstown, PA	198,300
192	Traverse City-Petoskey, MI	197,600
193	Dothan, AL	196,500
194	Topeka, KS	194,600
195	Amarillo, TX	192,600
196	Danbury, CT	189,400
197	Frederick, MD	188,500
198	Chico, CA	187,700
199	Tri-Cities, (Richland-Kennewick-Pasco), WA	187,500
200	Yakima, WA	186,900
201	Waco, TX	186,200
202	Rocky Mount-Wilson, NC	185,800
203	Clarksville-Hopkinsville, TN-KY	177,800
204	Duluth-Superior, MN-WI	175,500
205	Laredo, TX	174,900
206	Terre Haute, IN	173,900
207	Santa Maria-Lompoc, CA	173,100
208	Bowling Green, KY	172,400
209	Laurel-Hattiesburg, MS	172,300
210	Medford-Ashland, OR	171,000
211	Santa Barbara, CA	170,900
212	Muncie-Marion, IN	170,500
213	Cedar Rapids, IA	168,700
214	Sunbury-Selinsgrove-Lewisburg, PA	167,700
215	Olean, NY	167,600
216	Florence, SC	167,200
217	Bend, OR	166,100
218	St. Cloud, MN	164,800
219	Hilton Head, SC	164,500
220	Bangor, ME	163,500
221	Alexandria, LA	162,000
222	Champaign, IL	161,300
223	Elmira-Corning, NY	160,300
223	Fargo-Moorhead, ND-MN	160,300
225	Winchester, VA	159,800
226	Ft. Walton Beach, FL	159,600
227	Las Cruces, NM	159,200
228	Redding, CA	158,100
229	Lake Charles, LA	156,900
230	La Crosse, WI	155,300
231	Charlottesville, VA	152,500
232	Rochester, MN	151,400
233	Muskegon, MI	148,000
234	Tuscaloosa, AL	145,500
235	Dubuque, IA	142,200
236	Santa Fe, NM	140,700
237	Panama City, FL	140,600
238	Joplin, MO	140,500
239	Marion-Carbondale (Southern IL)	140,400
240	Bryan-College Station, TX	138,400
241	Bloomington, IL	137,000
242	Pittsburg, KS (Southeast Kansas)	136,300
243	Abilene, TX	136,100
244	Eau Claire, WI	135,500
245	Lafayette, IN	134,100
246	LaSalle-Peru, IL	131,700
247	Sussex, NJ	131,500
248	Wheeling, WV	129,500
249	Parkersburg-Marietta, WV-OH	128,500

Appendix A - ARBITRON RADIO MARKETS

250	Lima, OH	128,400
251	Waterloo-Cedar Falls, IA	128,300
252	Lufkin-Nacogdoches, TX	127,800
253	Pueblo, CO	127,700
254	State College, PA	126,400
255	Columbia, MO	124,700
256	Meadville-Franklin, PA	124,500
257	Monroe, LA	123,900
258	Florence-Muscle Shoals, AL	122,900
259	Billings, MT	118,500
260	Hamptons-Riverhead, NY	117,200
261	Battle Creek, MI	116,900
262	Kalispell-Flathead Valley, MT	115,500
263	Texarkana, TX-AR	114,400
264	Grand Junction, CO	113,200
265	Wichita Falls, TX	111,400
266	Montpelier-Barre-St. Johnsbury, VT	109,300
267	Altoona, PA	109,100
268	Augusta-Waterville, ME	106,800
269	Valdosta, GA	105,600
270	Albany, GA	104,700
271	Williamsport, PA	102,600
272	Elkins-Buckhannon-Weston, WV	101,900
273	Columbus-Starkville-West Point, MS	101,700
274	Mankato-New Ulm-St. Peter, MN	100,900
275	Sioux City, IA	100,300
276	Rapid City, SD	99,500
277	Harrisonburg, VA	99,300
278	Sheboygan, WI	99,000
279	Watertown, NY	98,300
280	Lewiston-Auburn, ME	94,100
281	Decatur, IL	92,200
282	Lawton, OK	91,800
283	Bluefield, WV	91,700
284	Ithaca, NY	90,100
285	Bismarck, ND	87,500
286	San Angelo, TX	86,000
287	Cookeville, TN	85,700
288	Sebring, FL	84,400
289	Grand Forks, ND-MN	83,300
290	Jackson, TN	80,200
291	Jonesboro, AR	74,200
292	Cheyenne, WY	72,500
293	The Florida Keys, FL	69,900
294	Beckley, WV	69,000
295	Mason City, IA	68,700
296	Great Falls, MT	67,500
297	Meridian, MS	66,600
298	Brunswick, GA	61,400
299	Casper, WY	60,300

Appendix B - STATION SELECTIONS FOR 50 LARGEST RADIO MARKETS

CPB Grantee	Call Letters	City	State	Arbitron Market
1	**New York, NY**		**15,325,000**	
WJFF-FM	WJFF-FM	JEFFERSONVILLE	NY	New York
WAMC-FM	WAMK-FM	KINGSTON	NY	New York
WBJB-FM	WBJB-FM	LINCROFT	NJ	New York
WAMC-FM	WOSR-FM	MIDDLETOWN	NY	New York
WFUV-FM	WFUV-FM	NEW YORK	NY	New York
WNYE-FM	WNYE-FM	NEW YORK	NY	New York
WBAI-FM	WBAI-FM	NEW YORK	NY	New York
WNYC-FM	WNYC-AM	NEW YORK	NY	New York
WNYC-FM	WNYC-FM	NEW YORK	NY	New York
WBGO-FM	WBGO-FM	NEWARK	NJ	New York
WMHT-FM	WRHV-FM	POUGHKEEPSIE	NY	New York
WPKT-FM	WRLI-FM	SOUTHAMPTON	NY	New York
WLIU-FM	WLIU-FM	SOUTHAMPTON	NY	New York
WPKT-FM	WEDW-FM	STAMFORD	CT	New York
WBFO-FM	WUSB-FM	STONY BROOK	NY	New York
WNJT-FM	WNJP-FM	SUSSEX	NJ	New York
2	**Los Angeles, CA**		**10,786,300**	
KCRW-FM	KCRY-FM	MOJAVE	CA	Los Angeles/Bakersfield
KKJZ-FM	KKJZ-FM	LONG BEACH	CA	Los Angeles
KCSN-FM	KCSN-FM	NORTHRIDGE	CA	Los Angeles
KPCC-FM	KPCC-FM	PASADENA	CA	Los Angeles
KVCR-FM	KVCR-FM	SAN BERNARDINO	CA	Los Angeles
KCRW-FM	KCRI-FM	INDIO	CA	Los Angeles/Palm Springs
3	**Chicago, IL**		**7,695,200**	
WBEZ-FM	WBEW-FM	CHESTERTON	IN	Chicago
WBEZ-FM	WBEZ-FM	CHICAGO	IL	Chicago
WRTE-FM	WRTE-FM	CHICAGO	IL	Chicago
WDCB-FM	WDCB-FM	GLEN ELLYN	IL	Chicago
WBEZ-FM	WBEQ-FM	MORRIS	IL	Chicago
4	**San Francisco, CA**		**5,825,800**	
KPFA-FM	KPFA-FM	BERKELEY	CA	San Fran/Fresno
KQED-FM	KQED-FM	SAN FRANCISCO	CA	San Fran/Monterey/Sacramento
KUSP-FM	KUSP-FM	SANTA CRUZ	CA	San Fran/Monterey-Salinas-Santa Cruz
KXPR-FM	KXSR-FM	GROVELAND	CA	San Fran/Sacramento/Fresno
KQED-FM	KQEI-FM	NORTH HIGHLANDS	CA	San Fran/Sacramento
KXPR-FM	KXPR-FM	SACRAMENTO	CA	San Fran/Sacramento
KXJZ-FM	KXJZ-FM	SACRAMENTO	CA	San Fran/Sacramento
KPFA-FM	KPFB-FM	BERKELEY	CA	San Francisco
KSOR-FM	KPMO-AM	MENDOCINO	CA	San Francisco
KZYX-FM	KZYX-FM	PHILO	CA	San Francisco
KALW-FM	KALW-FM	SAN FRANCISCO	CA	San Francisco

Appendix B - STATION SELECTIONS FOR 50 LARGEST RADIO MARKETS

KCSM-FM	KCSM-FM	SAN MATEO	CA	San Francisco
KRCB-FM	KRCB-FM	SANTA ROSA	CA	San Francisco
KBBF-FM	KBBF-FM	SANTA ROSA	CA	San Francisco
KZYX-FM	KZYZ-FM	WILLITS	CA	San Francisco
5	**Dallas-Ft. Worth, TX**		**4,728,000**	
KETR-FM	KETR-FM	COMMERCE	TX	Dallas-Ft Worth
KNON-FM	KNON-FM	DALLAS	TX	Dallas-Ft Worth
6	**Philadelphia, PA**		**4,352,600**	
WDIY-FM	WDIY-FM	ALLENTOWN	PA	Philadelphia
WNJT-FM	WNJN-FM	ATLANTIC CITY	NJ	Philadelphia
WNJT-FM	WNJS-FM	BERLIN	NJ	Philadelphia
WNJT-FM	WNJB-FM	BRIDGETON	NJ	Philadelphia
WWFM-FM	WWCJ-FM	CAPE MAY	NJ	Philadelphia
WNJT-FM	WNJZ-FM	CAPE MAY COURTHOU	SE NJ	Philadelphia
WRTI-FM	WRTX-FM	DOVER	DE	Philadelphia
WRTI-FM	WRTQ-FM	OCEAN CITY	NJ	Philadelphia
WWFM-FM	WWPJ-FM	PEN ARGYL	PA	Philadelphia
7	**Houston-Galveston, TX**		**4,350,900**	
KTSU-FM	KTSU-FM	HOUSTON	TX	Houston-Galveston
KUHF-FM	KUHF-FM	HOUSTON	TX	Houston-Galveston
KPVU-FM	KPVU-FM	PRAIRIE VIEW	TX	Houston-Galveston
KVLU-FM	KVLU-FM	BEAUMONT	TX	Houston-Galveston/Beaumont-Port Arthur
8	**Washington, DC**		**4,130,600**	
WYPR-FM	WYPR-FM	BALTIMORE	MD	Washing/Baltimore
WETA-FM	WETH-FM	HAGERSTOWN	MD	Washing/Baltimore
WETA-FM	WETA-FM	WASHINGTON	DC	Washing/Baltimore
WAMU-FM	WAMU-FM	WASHINGTON	DC	Washing/Richmon/Harrisb/Baltimore
WMRA-FM	WMRY-FM	CROZET	VA	Washing/Roanoke/Harriso/Charlottesville VA
WMRA-FM	WMRA-FM	HARRISONBURG	VA	Washing/Roanoke/Richmon/Harriso/Charlottesvil
WBJC-FM	WBJC-FM	BALTIMORE	MD	Washing/Salisbu/Harrisb/Baltimore
WPFW-FM	WPFW-FM	WASHINGTON	DC	Washington DC
WVPN-FM	WVEP-FM	MARTINSBURG	WV	Washington DC/Charleston WV
9	**Detroit, MI**		**3,890,300**	
WUOM-FM	WCBN-FM	ANN ARBOR	MI	Detroit
WDET-FM	WDET-FM	DETROIT	MI	Detroit
WEMU-FM	WEMU-FM	YPSILANTI	MI	Detroit
10	**Atlanta, GA**		**3,858,400**	
WUGA-FM	WUGA-FM	ATHENS	GA	Atlanta
WABE-FM	WABE-FM	ATLANTA	GA	Atlanta
WRFG-FM	WRFG-FM	ATLANTA	GA	Atlanta
WCLK-FM	WCLK-FM	ATLANTA	GA	Atlanta
WJSP-FM	WNGU-FM	DAHLONEGA	GA	Atlanta
WJSP-FM	WPPR-FM	DEMOREST	GA	Atlanta
11	**Boston, MA**		**3,839,200**	

Appendix B - STATION SELECTIONS FOR 50 LARGEST RADIO MARKETS

WUMB-FM	WUMB-FM	BOSTON	MA	Boston
WUMB-FM	WFPB-FM	FALMOUTH	MA	Boston
WEVO-FM	WEVN-FM	KEENE	NH	Boston
WUMB-FM	WNEF-FM	NEWBURYPORT	MA	Boston
WUMB-FM	WFPB-AM	ORLEANS	MA	Boston
WOMR-FM	WOMR-FM	PROVINCETOWN	MA	Boston
WUMB-FM	WBPR-FM	WORCESTER	MA	Boston
WICN-FM	WICN-FM	WORCESTER	MA	Boston
12	**Miami-Ft Lauderdale-Hollywd, FL**		**3,502,900**	
WDNA-FM	WDNA-FM	MIAMI	FL	Miami-Ft Lauderdale-Hollywood
13	**Puerto Rico (not Mrc Accredited)**		**3,249,000**	
WRTU-FM	WRUO-FM	MAYAGUEZ	PR	Puerto Rico
WIPR-FM	WIPR-AM	SAN JUAN	PR	Puerto Rico
WIPR-FM	WIPR-FM	SAN JUAN	PR	Puerto Rico
WRTU-FM	WRTU-FM	SAN JUAN	PR	Puerto Rico
14	**Seattle-Tacoma, WA**		**3,202,800**	
KBCS-FM	KBCS-FM	BELLEVUE	WA	Seattle-Tacoma
KWSU-AM	KZAZ-FM	BELLINGHAM	WA	Seattle-Tacoma
KSER-FM	KSER-FM	EVERETT	WA	Seattle-Tacoma
KWSU-AM	KMWS-FM	MOUNT VERNON	WA	Seattle-Tacoma
KAOS-FM	KAOS-FM	OLYMPIA	WA	Seattle-Tacoma
KWSU-AM	KNWP-FM	PORT ANGELES	WA	Seattle-Tacoma
KUOW-FM	KUOW-FM	SEATTLE	WA	Seattle-Tacoma
KPLU-FM	KPLU-FM	TACOMA	WA	Seattle-Tacoma
15	**Phoenix, AZ**		**2,936,800**	
KJZZ-FM	KJZA-FM	DRAKE	AZ	Phoenix
KNAU-FM	KNAU-FM	FLAGSTAFF	AZ	Phoenix
KNAU-FM	KPUB-FM	FLAGSTAFF	AZ	Phoenix
KNAU-FM	KNAG-FM	GRAND CANYON	AZ	Phoenix
KUYI-FM	KUYI-FM	HOTEVILLA	AZ	Phoenix
KNAU-FM	KNAD-FM	PAGE	AZ	Phoenix
KBAQ-FM	KBAQ-FM	PHOENIX	AZ	Phoenix
KUFW-FM	KNAI-FM	PHOENIX	AZ	Phoenix
KNAU-FM	KNAQ-FM	PRESCOTT	AZ	Phoenix
KNAU-FM	KNAA-FM	SHOW LOW	AZ	Phoenix
KGHR-FM	KGHR-FM	TUBA CITY	AZ	Phoenix
KNNB-FM	KNNB-FM	WHITERIVER	AZ	Phoenix
KAWC-AM	KAWC-AM	YUMA	AZ	Phoenix
KAWC-AM	KAWC-FM	YUMA	AZ	Phoenix
16	**Minneapolis-St. Paul, MN**		**2,630,600**	
KBPR-FM	KNCM-FM	APPLETON	MN	Minneapolis-St Paul
KBPR-FM	KRSU-FM	APPLETON	MN	Minneapolis-St Paul
KBPR-FM	KBPN-FM	BRAINERD	MN	Minneapolis-St Paul
KBPR-FM	KBPR-FM	BRAINERD	MN	Minneapolis-St Paul
KSJR-FM	KNSR-FM	COLLEGEVILLE	MN	Minneapolis-St Paul

Appendix B - STATION SELECTIONS FOR 50 LARGEST RADIO MARKETS

KSJR-FM	KSJR-FM	COLLEGEVILLE	MN	Minneapolis-St Paul
KFAI-FM	KFAI-FM	MINNEAPOLIS	MN	Minneapolis-St Paul
KBEM-FM	KBEM-FM	MINNEAPOLIS	MN	Minneapolis-St Paul
KUOM-AM	KUOM-AM	MINNEAPOLIS	MN	Minneapolis-St Paul
WHA -AM	WRFW-FM	RIVER FALLS	WI	Minneapolis-St Paul
KUOM-FM	KUOM-FM	SAINT LOUIS PARK	MN	Minneapolis-St Paul
KSJN-FM	KNOW-FM	SAINT PAUL	MN	Minneapolis-St Paul
KBPR-FM	KNSW-FM	WORTHINGTON	MN	Minneapolis-St Paul
KBPR-FM	KRSW-FM	WORTHINGTON	MN	Minneapolis-St Paul
WHA -AM	WVSS-FM	MENOMONIE	WI	Minneapolis-St Paul/Eau Claire
WHAD-FM	WHWC-FM	MENOMONIE	WI	Minneapolis-St Paul/Eau Claire
KSJN-FM	KSJN-FM	MINNEAPOLIS	MN	Minneapolis-St Paul/Eau Claire
17	**San Diego, CA**		**2,483,100**	
KPBS-FM	KPBS-FM	SAN DIEGO	CA	San Die/Los Angeles
KCRW-FM	KCRW-FM	SANTA MONICA	CA	San Die/Santa B/Los Ang/Bakersfield/Palm Springs
KUSC-FM	KUSC-FM	LOS ANGELES	CA	San Die/Santa B/Los Angeles/Palm Springs
KSJV-FM	KUBO-FM	CALEXICO	CA	San Diego
KSDS-FM	KSDS-FM	SAN DIEGO	CA	San Diego
18	**Nassau-Suffolk(Long Island), NY**		**2,391,900**	
19	**Tampa-St Petersburg-Clearwtr, FL**		**2,261,000**	
WGCU-FM	WMKO-FM	MARCO	FL	Tampa-S/Ft Myers-Naples-MarcoIsland
WMFE-FM	WMFE-FM	ORLANDO	FL	Tampa-S/Orlando
WUSF-FM	WUSF-FM	TAMPA	FL	Tampa-S/Orlando/Ft Myers-Naples-MarcoIsland
WUFT-FM	WJUF-FM	INVERNESS	FL	Tampa-S/Orlando/Gainesville-Ocala
WUFT-FM	WUFT-FM	GAINESVILLE	FL	Tampa-S/Orlando/Jackson/Gainesville-Ocala
WGCU-FM	WGCU-FM	FORT MYERS	FL	Tampa-S/Orlando/Miami-F/Ft Myers-Naples-Marco
WMNF-FM	WMNF-FM	TAMPA	FL	Tampa-St Petersbrg-Clearwater
20	**St. Louis, MO**		**2,260,300**	
KBIA-FM	KBIA-FM	COLUMBIA	MO	St Loui/Kansas/Columbia MO
WSIU-FM	WSIU-FM	CARBONDALE	IL	St Loui/Marion-Carbondale(SouthernIL)
KDHX-FM	KDHX-FM	SAINT LOUIS	MO	St Loui/Marion-Carbondale(SouthernIL)
KWMU-FM	KWMU-FM	SAINT LOUIS	MO	St Loui/Marion-Carbondale(SouthernIL)
KUMR-FM	KUMR-FM	ROLLA	MO	St Loui/Springfield MO
WSIE-FM	WSIE-FM	EDWARDSVILLE	IL	St Louis
WSIU-FM	WUSI-FM	OLNEY	IL	St Louis
KUMR-FM	KMNR-FM	ROLLA	MO	St Louis
WUIS-FM	WIPA-FM	PITTSFIELD	IL	St Louis/Champaign-Springfield DMA
21	**Baltimore, MD**		**2,248,100**	
WEAA-FM	WEAA-FM	BALTIMORE	MD	Baltimore
22	**Denver-Boulder, CO**		**2,155,900**	
KUCV-FM	KTNE-FM	ALLIANCE	NE	Denver-Boulder
KAJX-FM	KAJX-FM	ASPEN	CO	Denver-Boulder
KGNU-FM	KGNU-FM	BOULDER	CO	Denver-Boulder

Appendix B - STATION SELECTIONS FOR 50 LARGEST RADIO MARKETS

KVOD-FM	KCFC-AM	BOULDER	CO	Denver-Boulder
KUWR-FM	KBUW-FM	BUFFALO	WY	Denver-Boulder
KDNK-FM	KDNK-FM	CARBONDALE	CO	Denver-Boulder
KUCV-FM	KCNE-FM	CHADRON	NE	Denver-Boulder
KBUT-FM	KBUT-FM	CRESTED BUTTE	CO	Denver-Boulder
KVOD-FM	KCFR-AM	DENVER	CO	Denver-Boulder
KUVO-FM	KUVO-FM	DENVER	CO	Denver-Boulder
KEMC-FM	KYPR-FM	GILLETTE	WY	Denver-Boulder
KUNC-FM	KUNC-FM	GREELEY	CO	Denver-Boulder
KVOD-FM	KPRE-FM	VAIL	CO	Denver-Boulder
KUWR-FM	KUWG-FM	GILLETTE	WY	Denver-Boulder/Casper WY
KUWR-FM	KUWR-FM	LARAMIE	WY	Denver-Boulder/Casper WY
KVOD-FM	KPRU-FM	DELTA	CO	Denver-Boulder/Grand Junction
KVOD-FM	KPRN-FM	GRAND JUNCTION	CO	Denver-Boulder/Grand Junction
KVOD-FM	KPRH-FM	MONTROSE	CO	Denver-Boulder/Grand Junction
KVNF-FM	KVNF-FM	PAONIA	CO	Denver-Boulder/Grand Junction
23	**Pittsburgh, PA**		**2,013,000**	
WQED-FM	WQEJ-FM	JOHNSTOWN	PA	Pittsbu/Altoona
WQED-FM	WQED-FM	PITTSBURGH	PA	Pittsbu/Altoona
WYEP-FM	WYEP-FM	PITTSBURGH	PA	Pittsburgh PA
WDUQ-FM	WDUQ-FM	PITTSBURGH	PA	Pittsburgh PA
WVPN-FM	WVPM-FM	MORGANTOWN	WV	Pittsburgh PA/Morgantown
WVPN-FM	WVNP-FM	WHEELING	WV	Pittsburgh PA/Wheeling
24	**Portland, OR**		**1,961,900**	
KMUN-FM	KMUN-FM	ASTORIA	OR	Portland OR
KMHD-FM	KMHD-FM	GRESHAM	OR	Portland OR
KBPS-FM	KQHR-FM	HOOD RIVER	OR	Portland OR
KOPB-FM	KTVR-FM	LA GRANDE	OR	Portland OR
KOPB-FM	KOAP-FM	LAKEVIEW	OR	Portland OR
KBOO-FM	KBOO-FM	PORTLAND	OR	Portland OR
KBPS-FM	KBPS-AM	PORTLAND	OR	Portland OR
KBPS-FM	KBPS-FM	PORTLAND	OR	Portland OR
25	**Cleveland, OH**		**1,798,400**	
WAPS-FM	WAPS-FM	AKRON	OH	Cleveland
WCPN-FM	WCPN-FM	CLEVELAND	OH	Cleveland
WKSU-FM	WKRJ-FM	NEW PHILADELPHIA	OH	Cleveland
WKSU-FM	WKRW-FM	WOOSTER	OH	Cleveland
26	**Sacramento, CA**		**1,756,300**	
KSJV-FM	KMPO-FM	MODESTO	CA	Sacrame/Fresno
KXJZ-FM	KUOP-FM	STOCKTON	CA	Sacrame/Fresno
KXJZ-FM	KKTO-FM	TAHOE CITY	CA	Sacrame/Reno
KVMR-FM	KVMR-FM	NEVADA CITY	CA	Sacramento
KCHO-FM	KCHO-FM	CHICO	CA	Sacramento/Redding
27	**Riverside-San Bernardino, CA**		**1,755,700**	
28	**Cincinnati, OH**		**1,703,800**	

Appendix B - STATION SELECTIONS FOR 50 LARGEST RADIO MARKETS

WNKU-FM	WNKU-FM	HIGHLAND HEIGHTS	KY	Cincinnati
WGUC-FM	WVXW-FM	WEST UNION	OH	Cincinnati
29	**Kansas City, KS-MO**		**1,551,700**	
KANU-FM	KJHK-FM	LAWRENCE	KS	Kansas City
KCUR-FM	KCUR-FM	KANSAS CITY	MO	Kansas City
KKFI-FM	KKFI-FM	KANSAS CITY	MO	Kansas City
KXCV-FM	KRNW-FM	CHILLICOTHE	MO	Kansas City
30	**San Antonio, TX**		**1,550,600**	
KEDT-FM	KEDT-FM	CORPUS CHRISTI	TX	San Ant/Corpus Christi
KEDT-FM	KVRT-FM	VICTORIA	TX	San Ant/Houston/Corpus Christi
KPAC-FM	KPAC-FM	SAN ANTONIO	TX	San Antonio
KPAC-FM	KSTX-FM	SAN ANTONIO	TX	San Antonio
KPAC-FM	KTXI-FM	INGRAM	TX	San Antonio
31	**Salt Lake City-Ogden-Provo, UT**		**1,484,300**	
KNPR-FM	KWPR-FM	LUND	NV	Salt Lake City-Ogden-Provo
KUNR-FM	KNCC-FM	ELKO	NV	Salt Lake City-Ogden-Provo
KUSU-FM	KUSR-FM	LOGAN	UT	Salt Lake City-Ogden-Provo
KUSU-FM	KUSU-FM	LOGAN	UT	Salt Lake City-Ogden-Provo
KZMU-FM	KZMU-FM	MOAB	UT	Salt Lake City-Ogden-Provo
KPCW-FM	KCPW-FM	SALT LAKE CITY	UT	Salt Lake City-Ogden-Provo
KPCW-FM	KCUA-FM	COALVILLE	UT	Salt Lake City-Ogden-Provo
KPCW-FM	KPCW-FM	PARK CITY	UT	Salt Lake City-Ogden-Provo
KBYU-FM	KBYU-FM	PROVO	UT	Salt Lake City-Ogden-Provo
KRCL-FM	KRCL-FM	SALT LAKE CITY	UT	Salt Lake City-Ogden-Provo
KUER-FM	KUER-FM	SALT LAKE CITY	UT	Salt Lake City-Ogden-Provo
KUWR-FM	KUWX-FM	PINEDALE	WY	Salt Lake City-Ogden-Provo
32	**Las Vegas, NV**		**1,437,600**	
KCEP-FM	KCEP-FM	LAS VEGAS	NV	Las Vegas
KNPR-FM	KCNV-FM	LAS VEGAS	NV	Las Vegas
KNPR-FM	KLNR-FM	PANACA	NV	Las Vegas
KNPR-FM	KTPH-FM	TONOPAH	NV	Las Vegas
KUNV-FM	KUNV-FM	LAS VEGAS	NV	Las Vegas
33	**Milwaukee-Racine, WI**		**1,427,700**	
WHA -AM	WSUW-FM	WHITEWATER	WI	Milwaukee-Racine
WUWM-FM	WUWM-FM	MILWAUKEE	WI	Milwaukee-Racine
WYMS-FM	WYMS-FM	MILWAUKEE	WI	Milwaukee-Racine
34	**San Jose, CA**		**1,411,800**	
35	**Charlotte-Gastonia-Rock Hl,NC-SC**		**1,408,700**	
WDAV-FM	WDAV-FM	DAVIDSON	NC	Charlotte-Gastonia-Rock Hill
36	**Providence-Warwick-Pawtucket, RI**		**1,402,600**	
WBUR-FM	WBUR-AM	WEST YARMOUTH	MA	Provide/Boston
WBUR-FM	WBUR-FM	BOSTON	MA	Provide/Boston
WGBH-FM	WCAI-FM	WOODS HOLE	MA	Provide/Boston
WGBH-FM	WNAN-FM	NANTUCKET	MA	Provide/Boston

Appendix B - STATION SELECTIONS FOR 50 LARGEST RADIO MARKETS

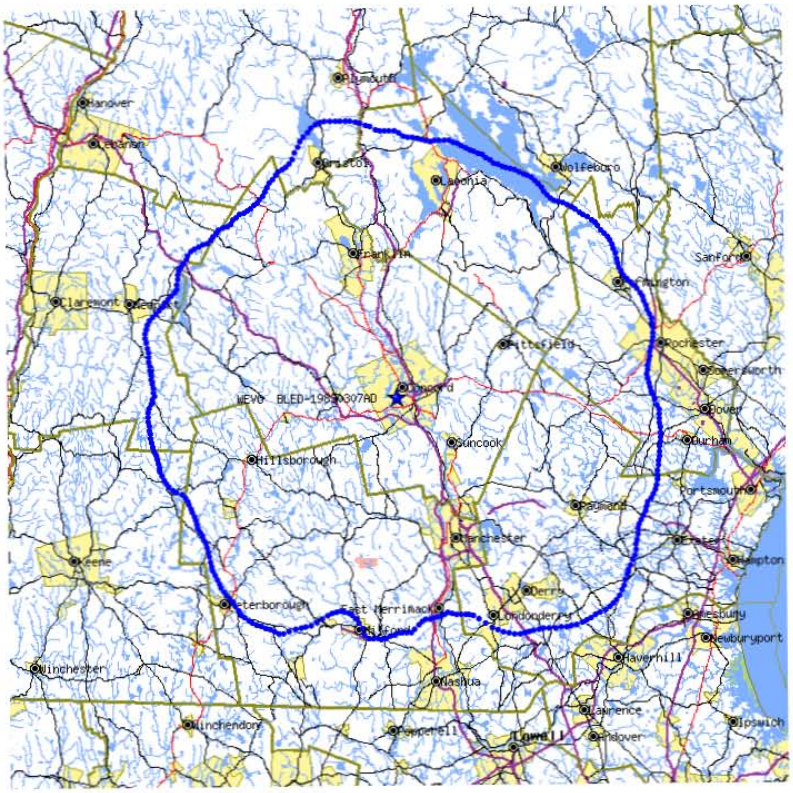
WBUR-FM	WRNI-AM	PROVIDENCE	RI	Provide/Boston
WPKT-FM	WNPR-FM	NORWICH	CT	Provide/New Yor/Hartford-NewBritain-Middltwn
WPKT-FM	WPKT-FM	MERIDEN	CT	Provide/New Yor/Hartford-NewBritain-Middltwn
WSHU-FM	WSUF-FM	NOYACK	NY	Provide/New Yor/Hartford-NewBritain-Middltwn
WBUR-FM	WXNI-AM	WESTERLY	RI	Providence
37	**Orlando, FL**		**1,400,800**	
WFIT-FM	WFIT-FM	MELBOURNE	FL	Orlando
WUCF-FM	WUCF-FM	ORLANDO	FL	Orlando
38	**Columbus, OH**		**1,399,900**	
WOUB-FM	WOUB-AM	ATHENS	OH	Columbus OH
WOUB-FM	WOUH-FM	CHILLICOTHE	OH	Columbus OH
WOUB-FM	WOUZ-FM	ZANESVILLE	OH	Columbus OH
WVXU-FM	WVXC-FM	CHILLICOTHE	OH	Columbus OH
WCBE-FM	WCBE-FM	COLUMBUS	OH	Columbus OH
WOSU-FM	WOSB-FM	MARION	OH	Columbus OH
WOSU-FM	WOSE-FM	COSHOCTON	OH	Columbus OH
WOSU-FM	WOSP-FM	PORTSMOUTH	OH	Columbus OH/Charleston WV
39	**Middlesex-Somerset-Union, NJ**		**1,381,900**	
40	**Norfolk-Vrginia Bch-Nwprt Nws,VA**		**1,313,200**	
WUNC-FM	WURI-FM	MANTEO	NC	Norfolk-VaBeach-Newport News
WHRV-FM	WHRO-FM	NORFOLK	VA	Norfolk-VaBeach-Newport News
WHRV-FM	WHRV-FM	NORFOLK	VA	Norfolk-VaBeach-Newport News
WNSB-FM	WNSB-FM	NORFOLK	VA	Norfolk-VaBeach-Newport News
41	**Indianapolis, IN**		**1,310,800**	
WFYI-FM	WFYI-FM	INDIANAPOLIS	IN	Indianapolis
WBST-FM	WBSB-FM	ANDERSON	IN	Indianapolis
WBST-FM	WBSW-FM	MARION	IN	Indianapolis
42	**Austin, TX**		**1,203,500**	
43	**Raleigh-Durham, NC**		**1,142,600**	
WNCU-FM	WNCU-FM	DURHAM	NC	Raleigh-Durham
WZRU-FM	WZRN-FM	NORLINA	NC	Raleigh-Durham
WZRU-FM	WZRU-FM	ROANOKE RAPIDS	NC	Raleigh-Durham
WSHA-FM	WSHA-FM	RALEIGH	NC	Raleigh-Durham
44	**Nashville, TN**		**1,123,800**	
WMOT-FM	WMOT-FM	MURFREESBORO	TN	Nashville
WPLN-FM	WHRS-FM	COOKEVILLE	TN	Nashville
WPLN-FM	WPLN-AM	MADISON	TN	Nashville
WPLN-FM	WPLN-FM	NASHVILLE	TN	Nashville
WPLN-FM	WTML-FM	TULLAHOMA	TN	Nashville
45	**Greensboro-Winstn Salem-Hi Pt,NC**		**1,112,200**	
WFDD-FM	WFDD-FM	WINSTON-SALEM	NC	Greensboro-WnstnSalm-HighPnt
46	**West Palm Beach-Boca Raton, FL**		**1,097,000**	
WXEL-FM	WXEL-FM	WEST PALM BEACH	FL	West Pa/Miami-Ft Lauderdale-Hollywood

Appendix B - STATION SELECTIONS FOR 50 LARGEST RADIO MARKETS

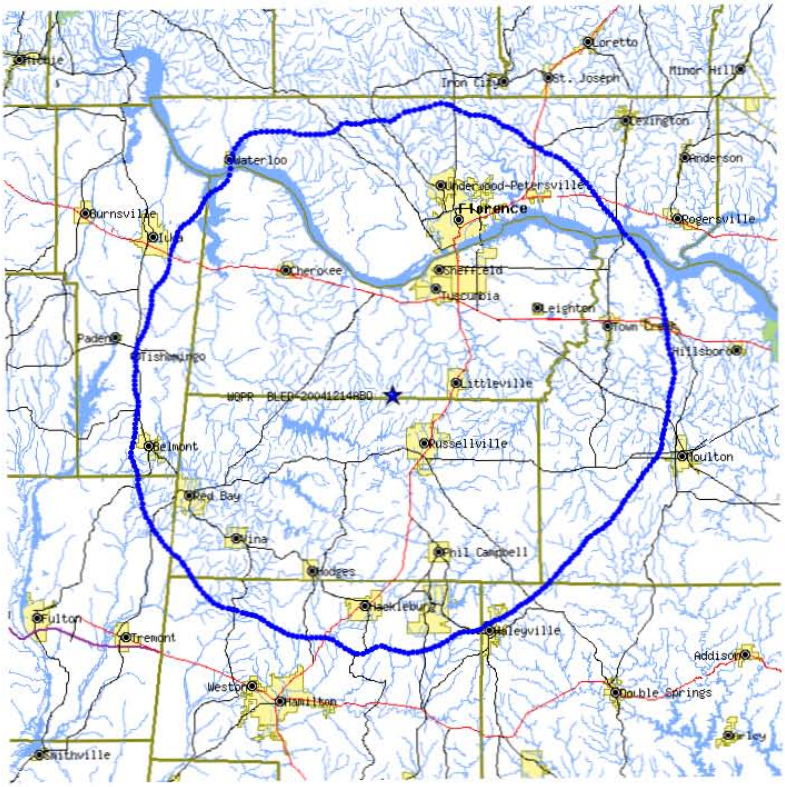
WLRN-FM	WLRN-FM	MIAMI	FL	West Pa/Miami-Ft Lauderdale-Hollywood
47	**Oklahoma City, OK**		**1,058,200**	
KCCU-FM	KYCU-FM	CLINTON	OK	Oklahoma City
KGOU-FM	KGOU-FM	NORMAN	OK	Oklahoma City
KGOU-FM	KROU-FM	SPENCER	OK	Oklahoma City
48	**Jacksonville, FL**		**1,056,500**	
WJCT-FM	WJCT-FM	JACKSONVILLE	FL	Jacksonville
49	**Memphis, TN**		**1,047,200**	
WURC-FM	WURC-FM	HOLLY SPRINGS	MS	Memphis
WKNO-FM	WKNA-FM	SENATOBIA	MS	Memphis
WKNO-FM	WKNP-FM	JACKSON	TN	Memphis
50	**Hartford-New Britain-Middletn,CT**		**1,042,700**	
WMNR-FM	WGSK-FM	SOUTH KENT	CT	Hartford-NewBritain-Middltwn
WHUS-FM	WHUS-FM	STORRS	CT	Hartford-NewBritain-Middltwn

Appendix C - MAPS OF 25 SMALLER-MARKET STATIONS SELECTED FOR STUDY

1 - WEVO, Concord NH

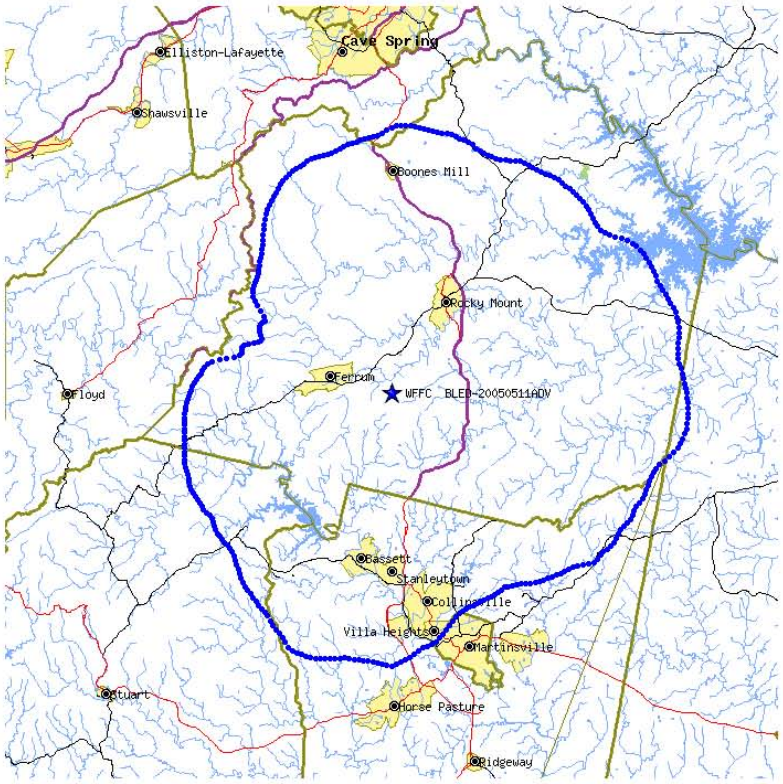


2 - WQPR, Muscle Shoals AL

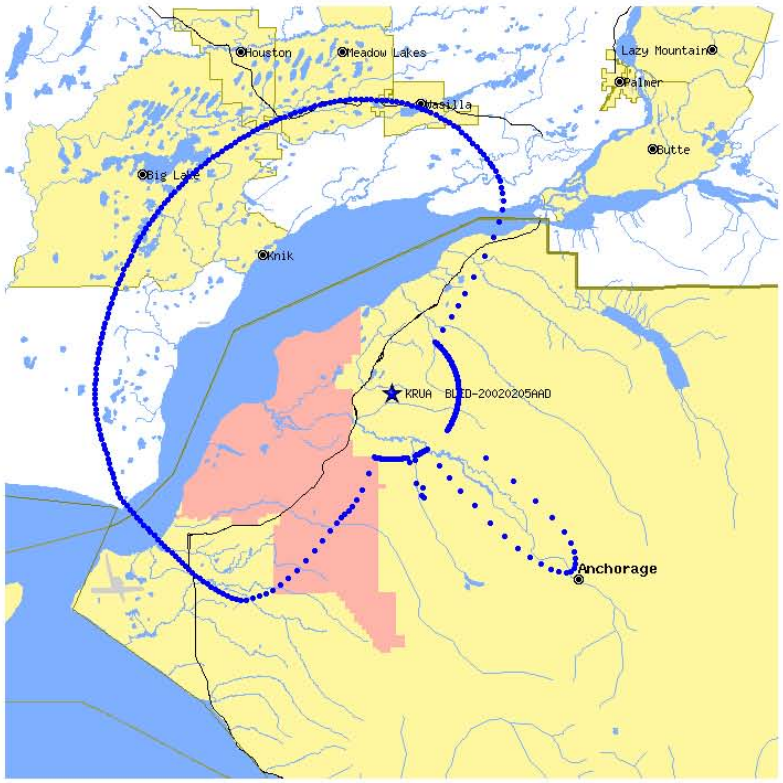


Appendix C - MAPS OF 25 SMALLER-MARKET STATIONS SELECTED FOR STUDY

3 - WFFC, Ferrum VA

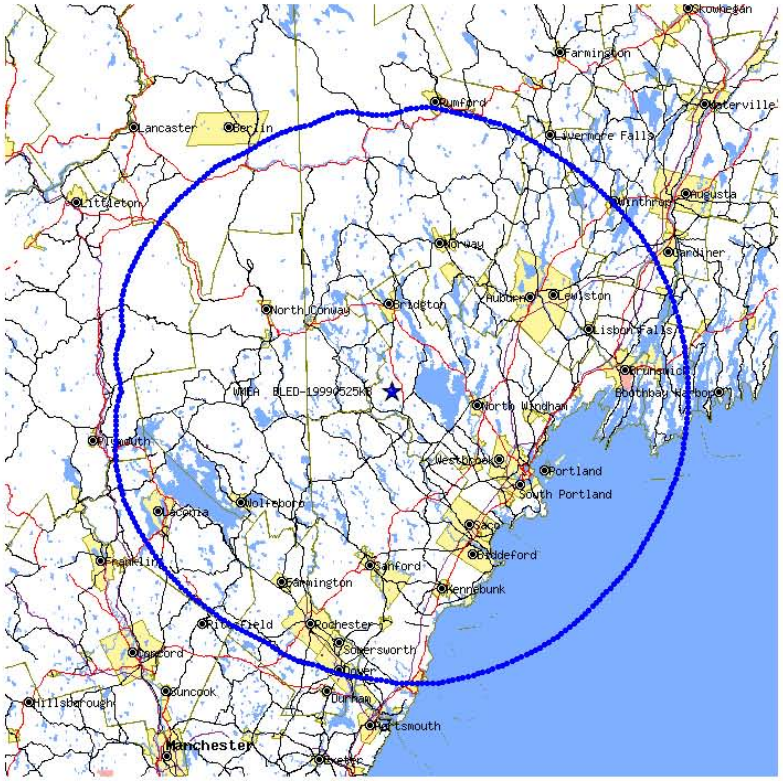


4 - KRUA, Anchorage AK

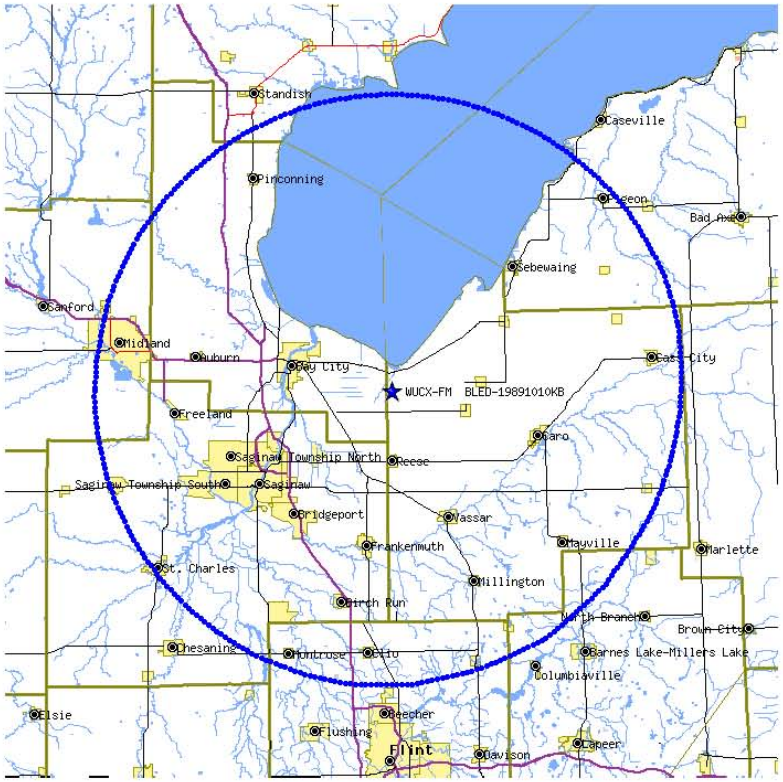


Appendix C - MAPS OF 25 SMALLER-MARKET STATIONS SELECTED FOR STUDY

5 - WMEA, Portland ME

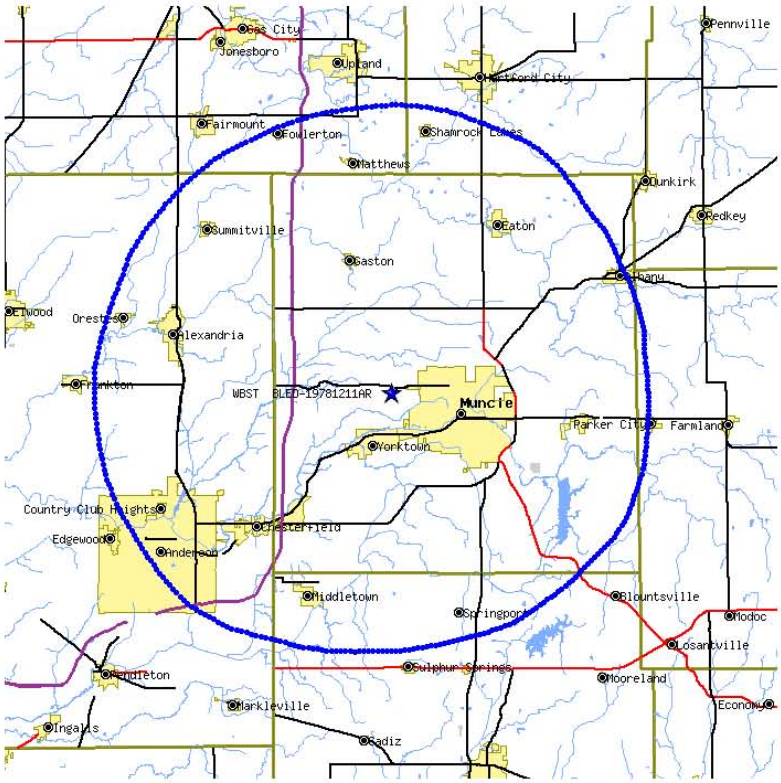


6 - WUCX, Bay City MI

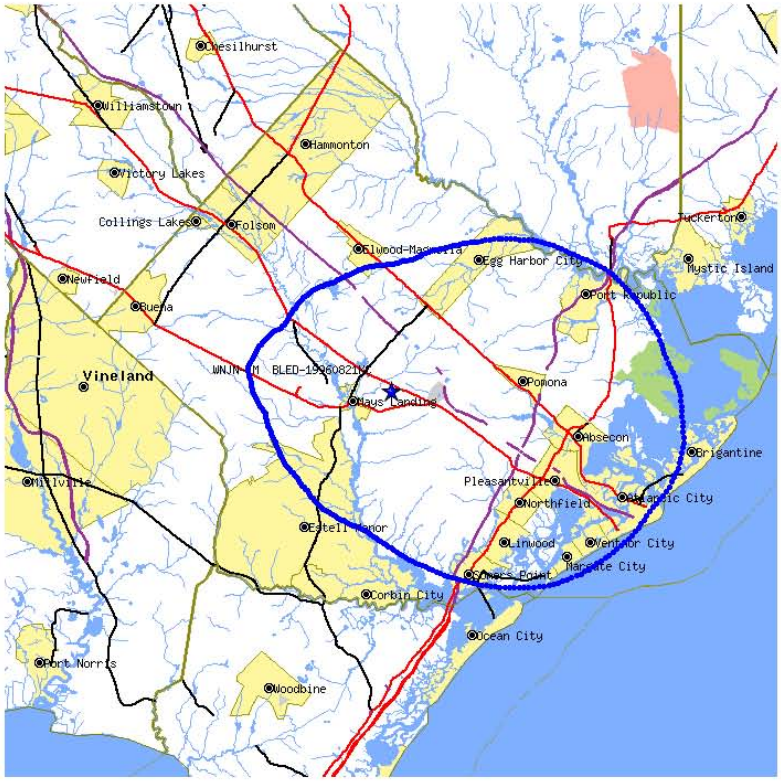


Appendix C - MAPS OF 25 SMALLER-MARKET STATIONS SELECTED FOR STUDY

7 - WBST, Muncie IN

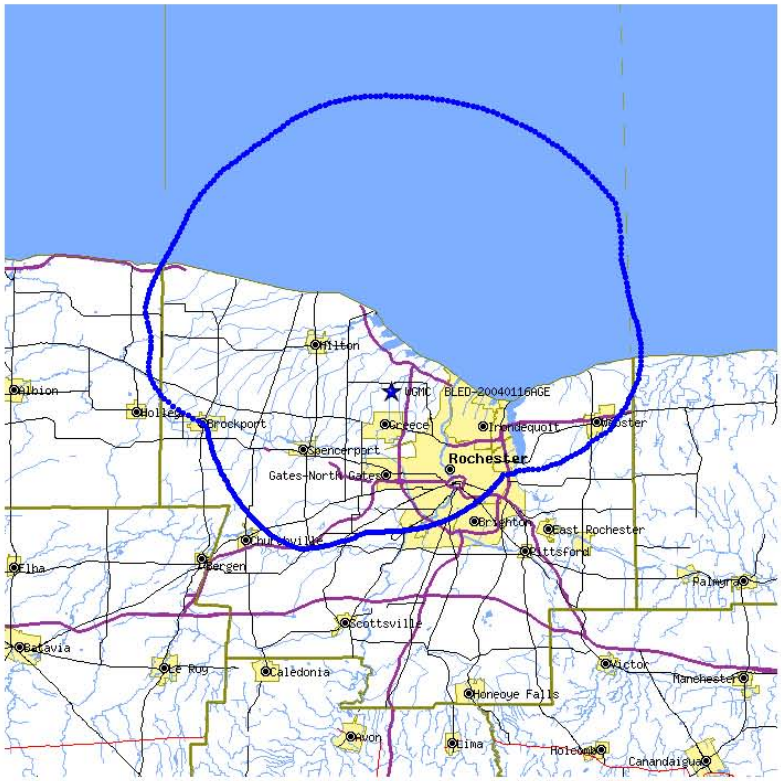


8 - WNJN, Atlantic City NJ

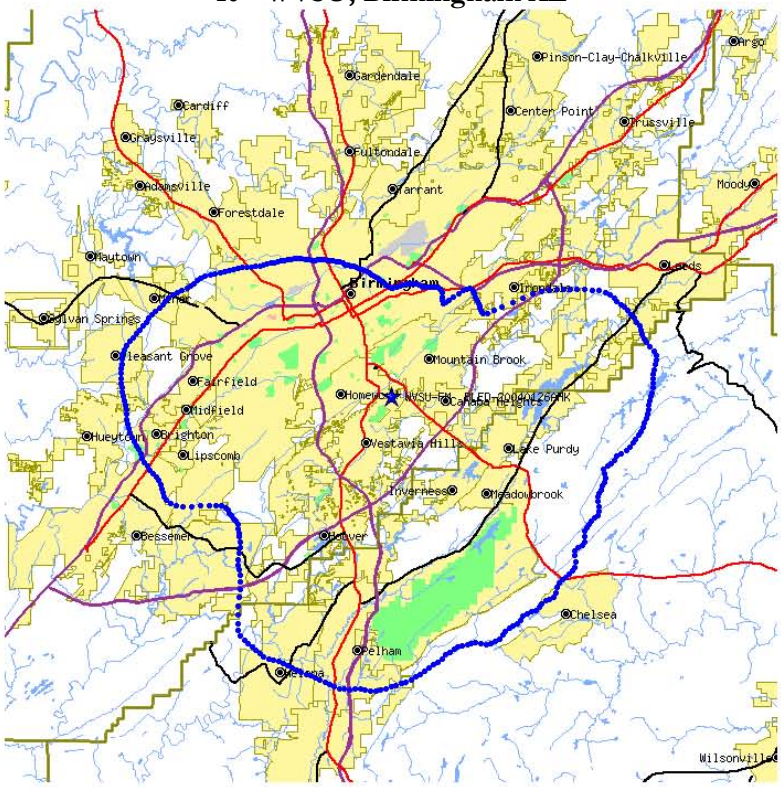


Appendix C - MAPS OF 25 SMALLER-MARKET STATIONS SELECTED FOR STUDY

9 - WGMC, Rochester MN



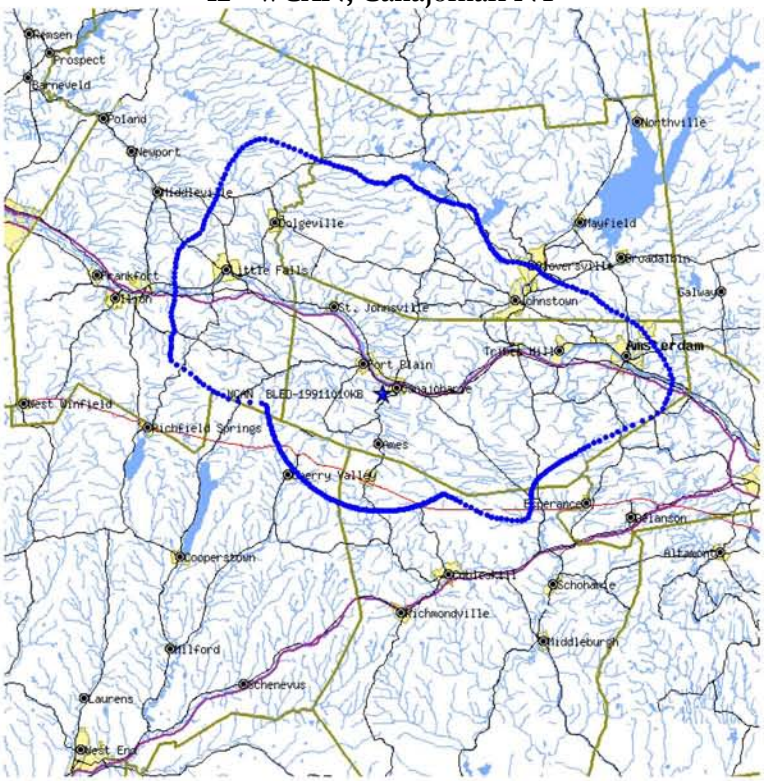
10 - WVSU, Birmingham AL



Appendix C - MAPS OF 25 SMALLER-MARKET STATIONS SELECTED FOR STUDY

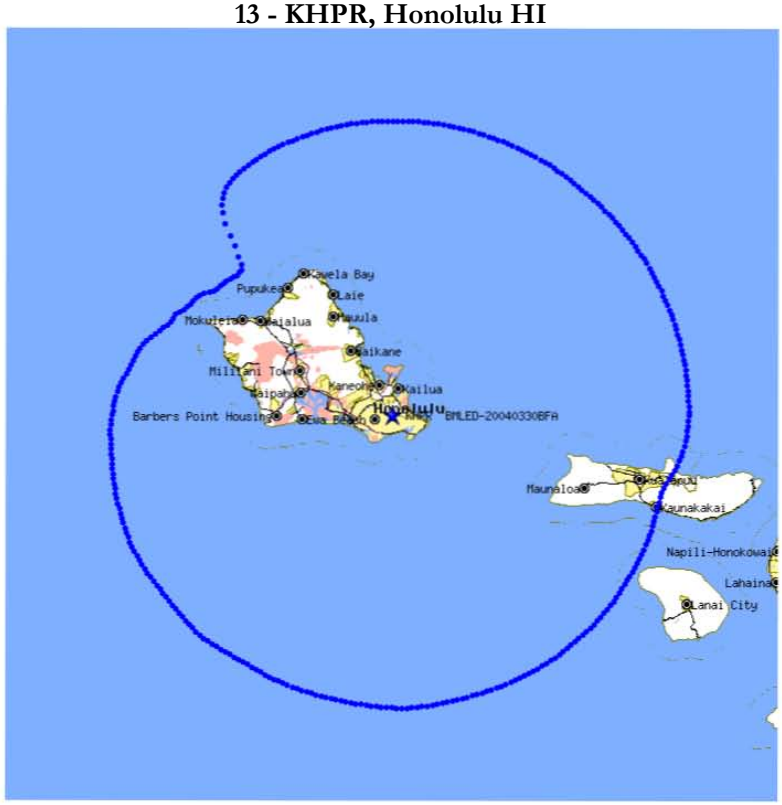
11 - KHID, McAllen TX

12 - WCAN, Canajorhari NY

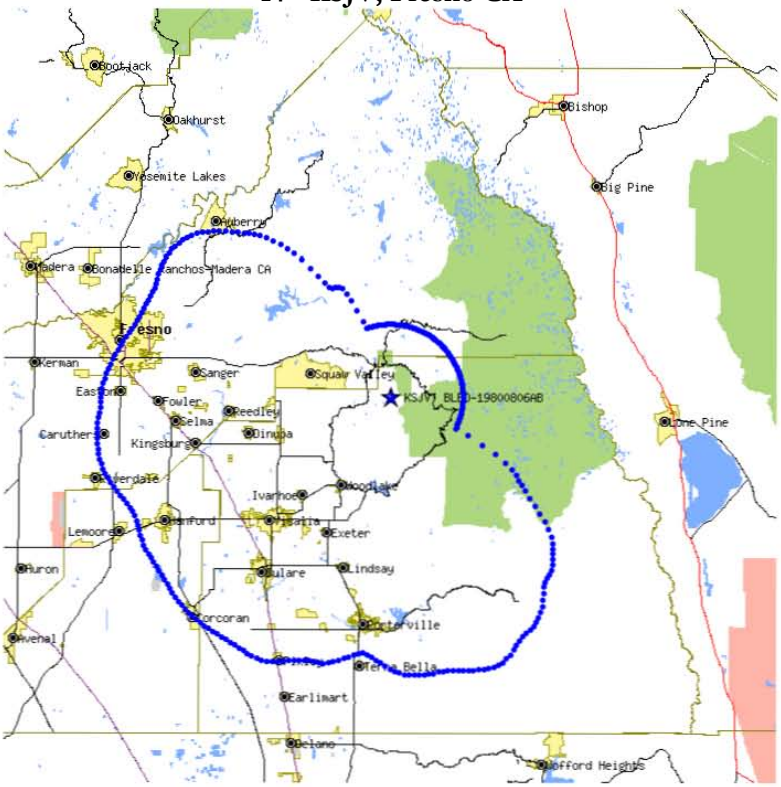


Appendix C - MAPS OF 25 SMALLER-MARKET STATIONS SELECTED FOR STUDY

13 - KHPR, Honolulu HI

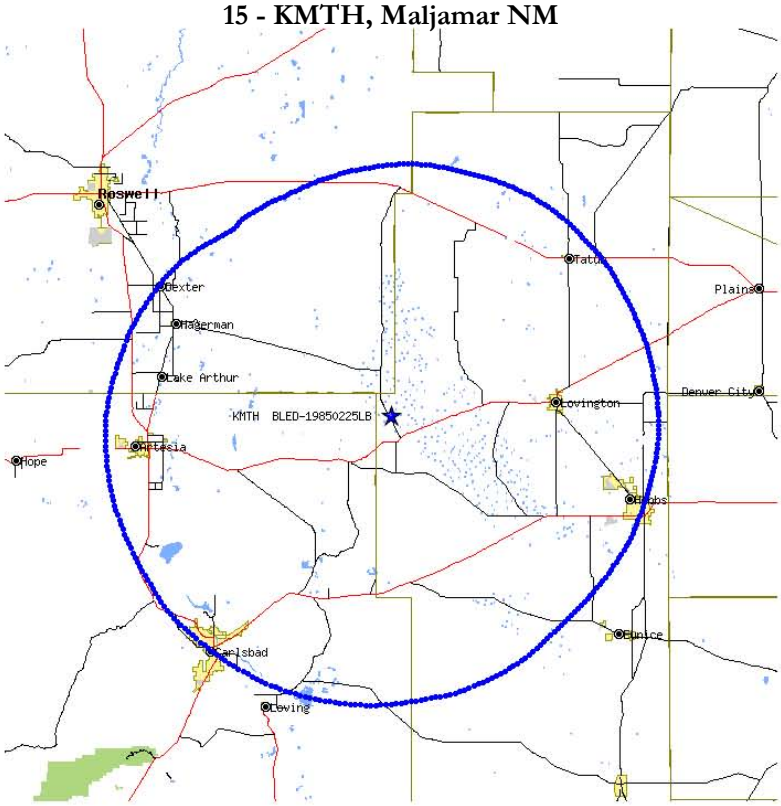


14 - KSJV, Fresno CA



Appendix C - MAPS OF 25 SMALLER-MARKET STATIONS SELECTED FOR STUDY

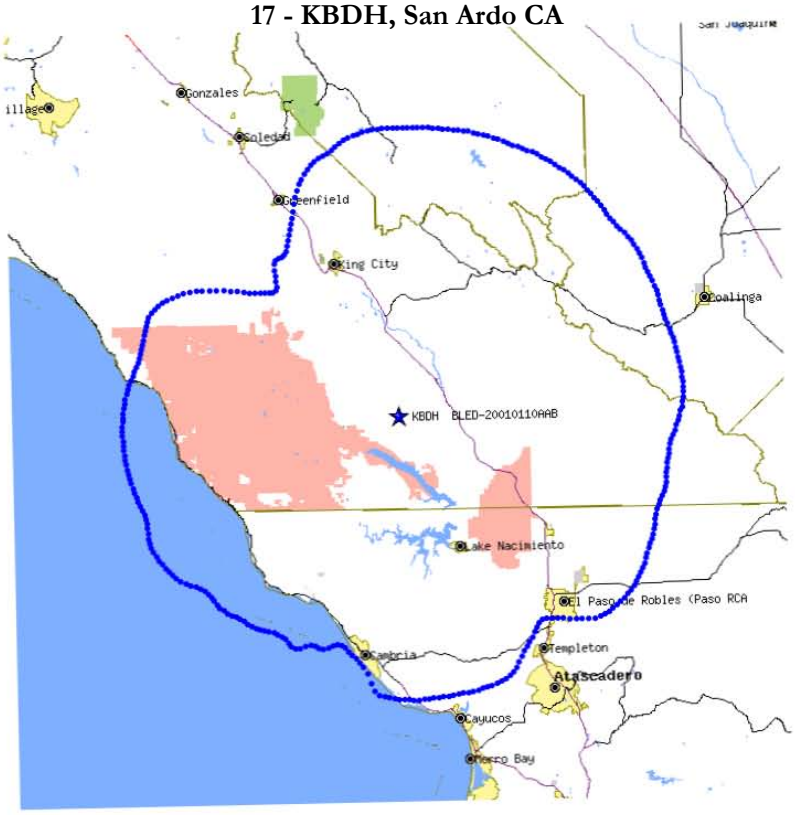
15 - KMTH, Maljamar NM



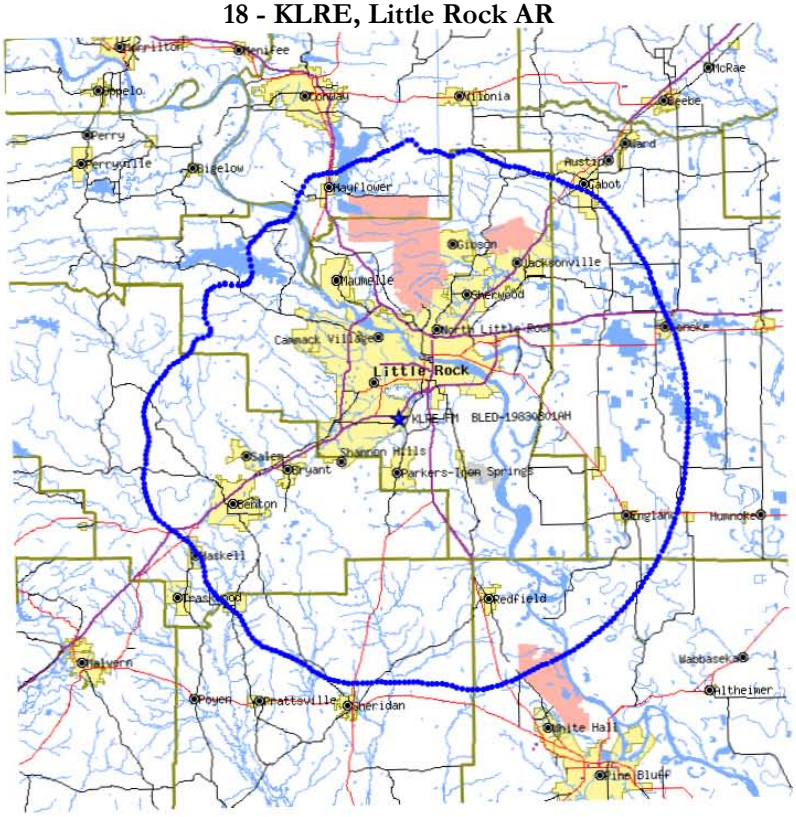
16 - KAZU, Santa Cruz CA

Appendix C - MAPS OF 25 SMALLER-MARKET STATIONS SELECTED FOR STUDY

17 - KBDH, San Ardo CA

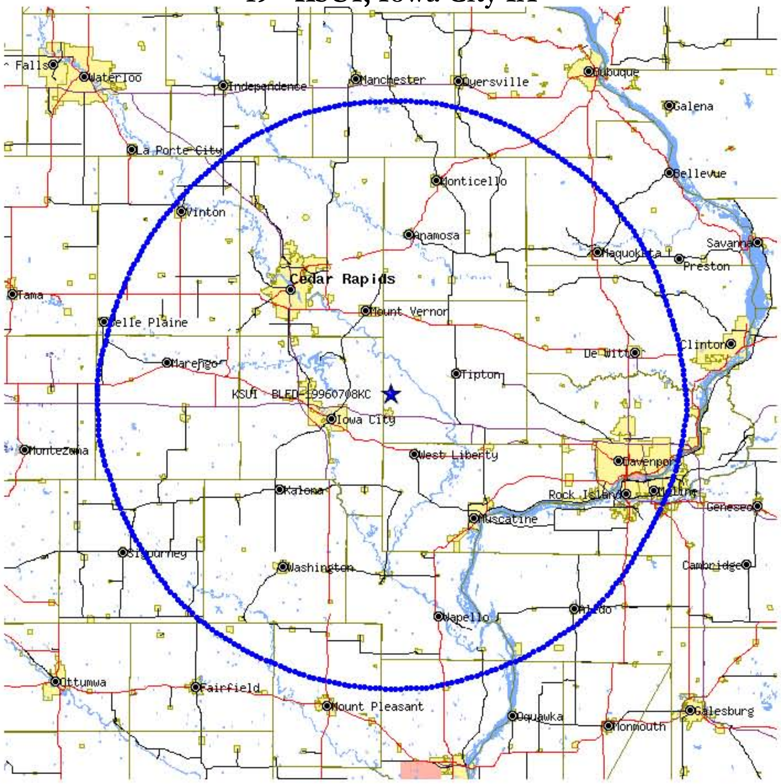


18 - KLRE, Little Rock AR

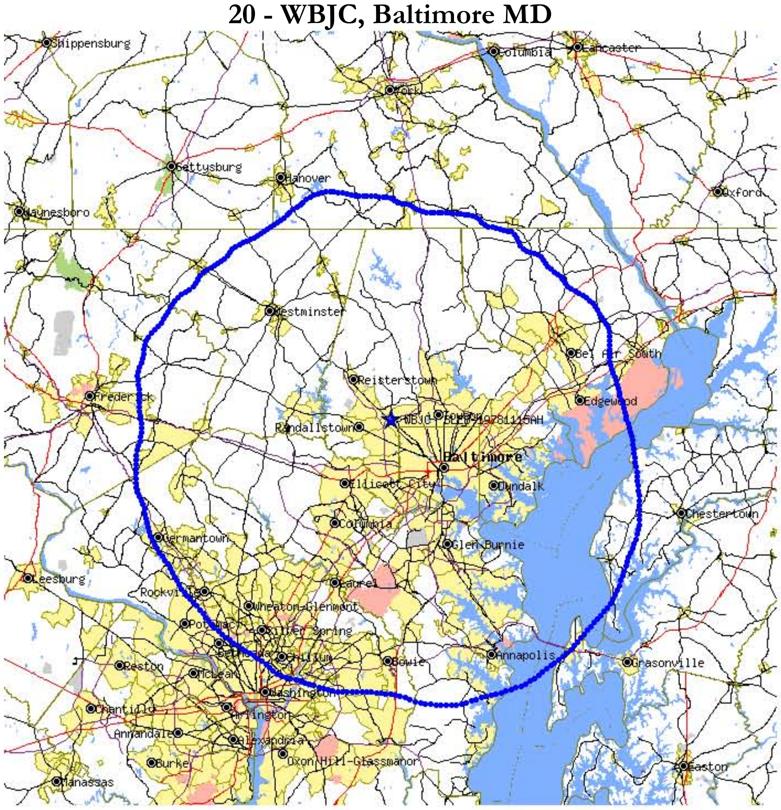


Appendix C - MAPS OF 25 SMALLER-MARKET STATIONS SELECTED FOR STUDY

19 - KSUI, Iowa City IA

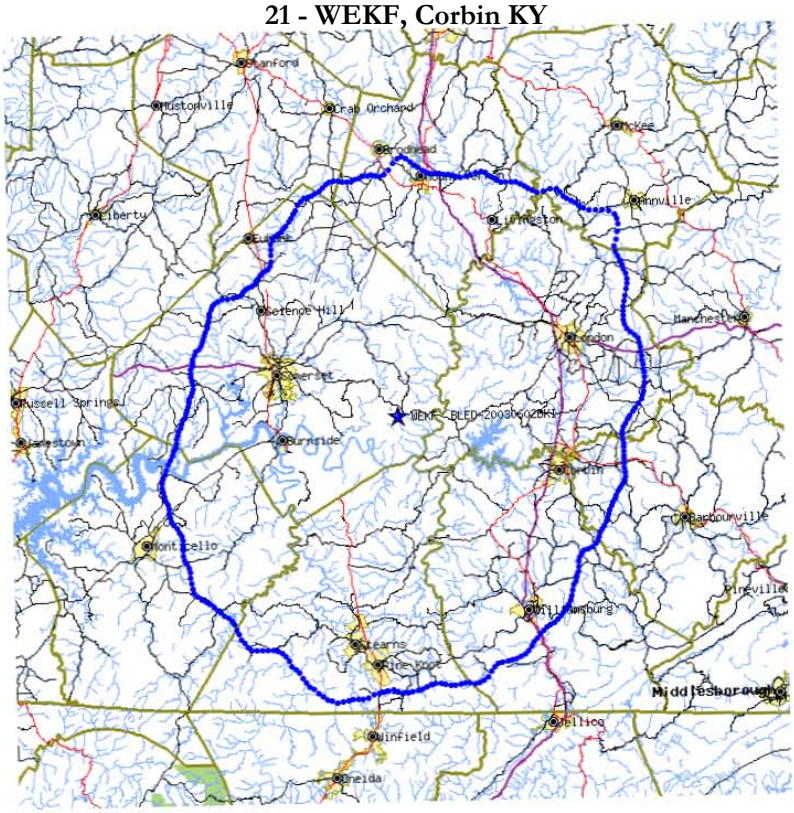


20 - WBJC, Baltimore MD

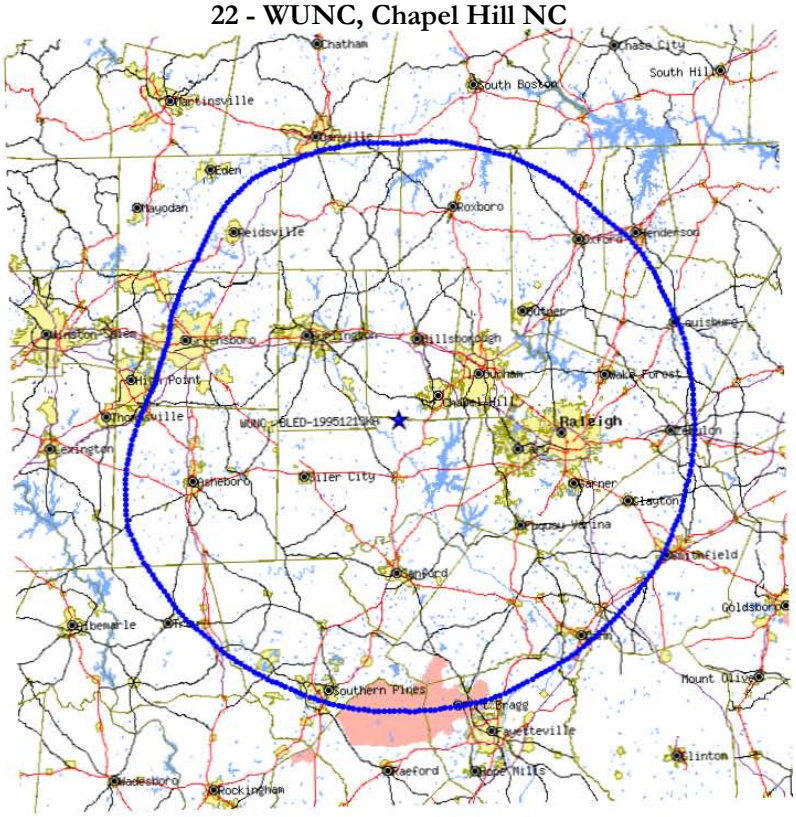


Appendix C - MAPS OF 25 SMALLER-MARKET STATIONS SELECTED FOR STUDY

21 - WEKF, Corbin KY

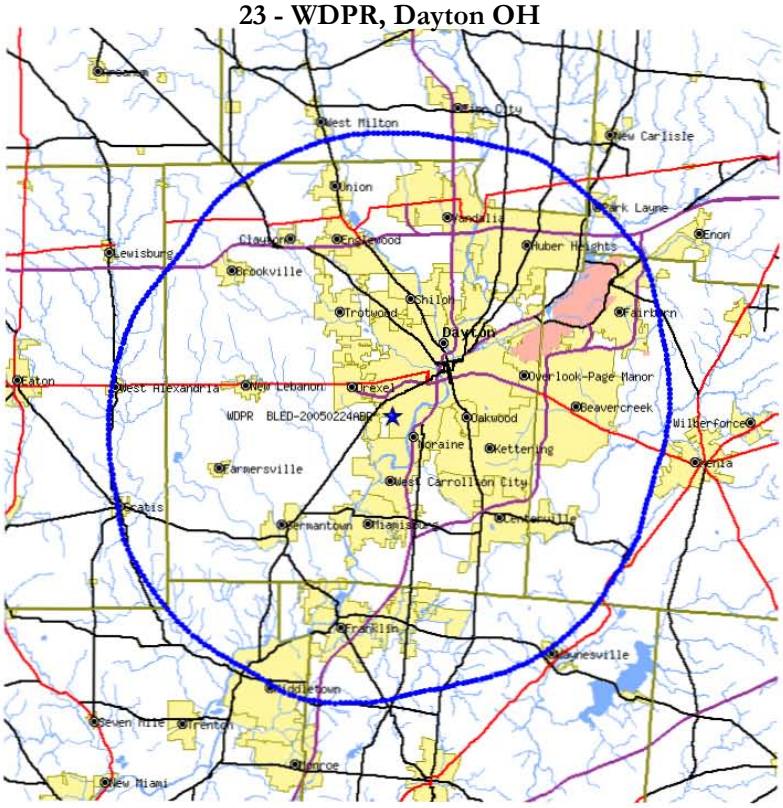


22 - WUNC, Chapel Hill NC

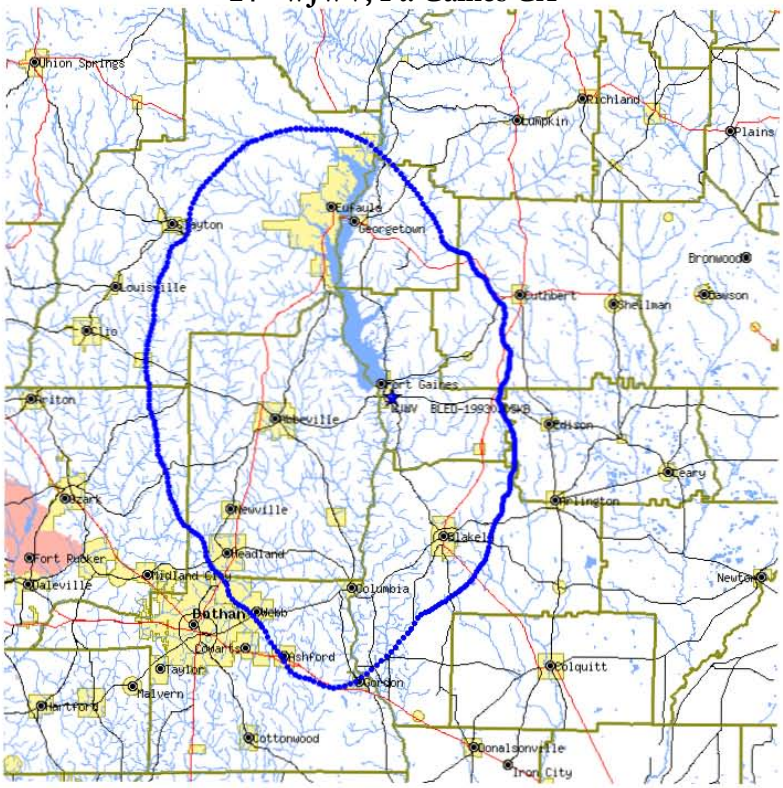


Appendix C - MAPS OF 25 SMALLER-MARKET STATIONS SELECTED FOR STUDY

23 - WDPR, Dayton OH

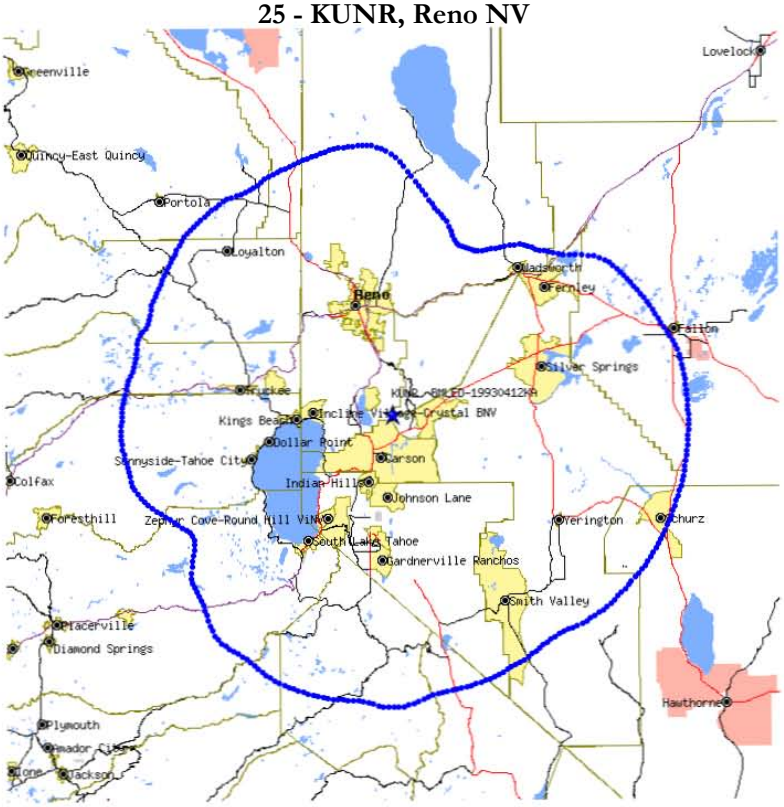


24 - WJWV, Ft. Gaines GA

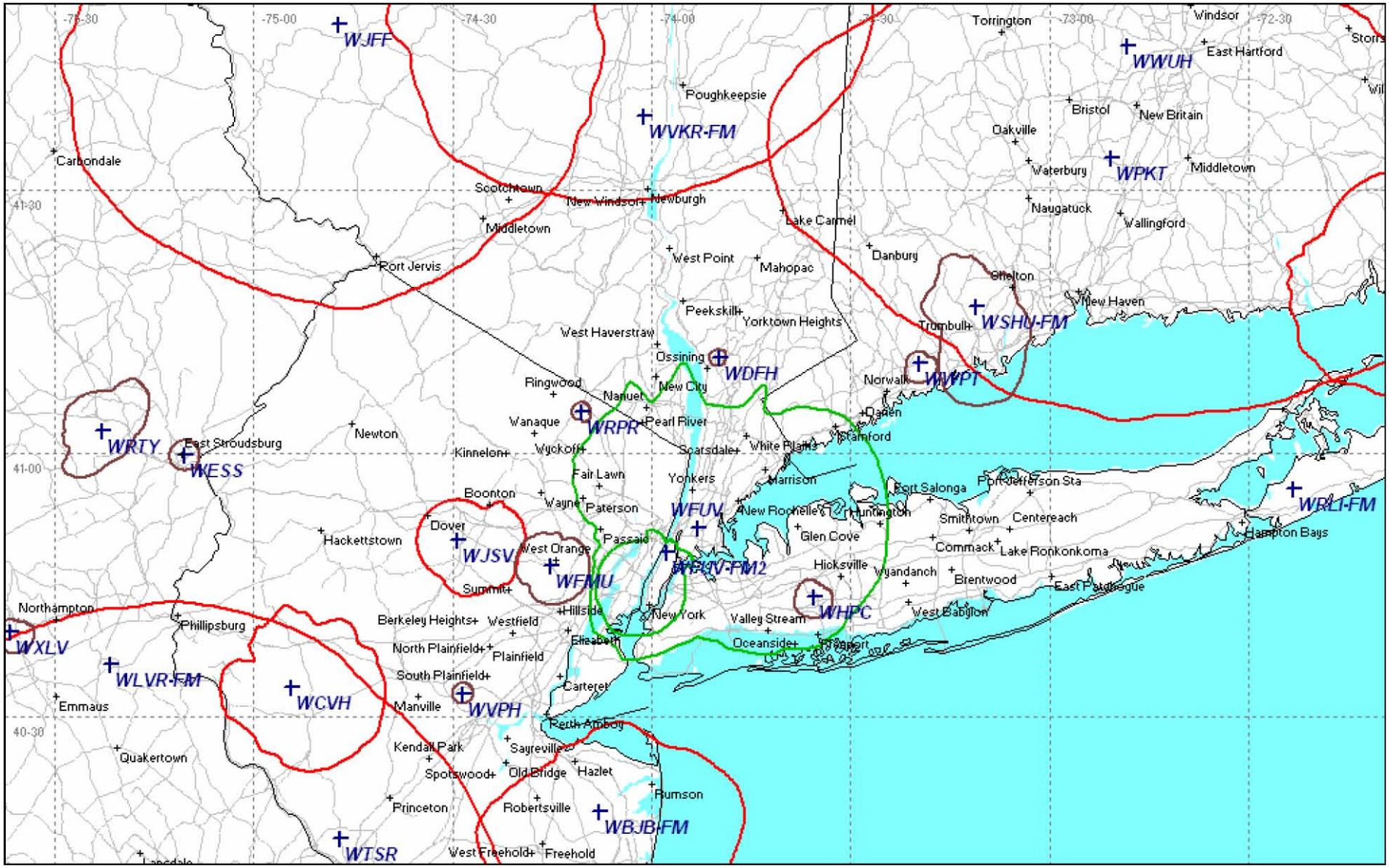


Appendix C - MAPS OF 25 SMALLER-MARKET STATIONS SELECTED FOR STUDY

25 - KUNR, Reno NV



Appendix D - MAPS OF 10 CANDIDATE STATIONS SELECTED FOR MEASUREMENT



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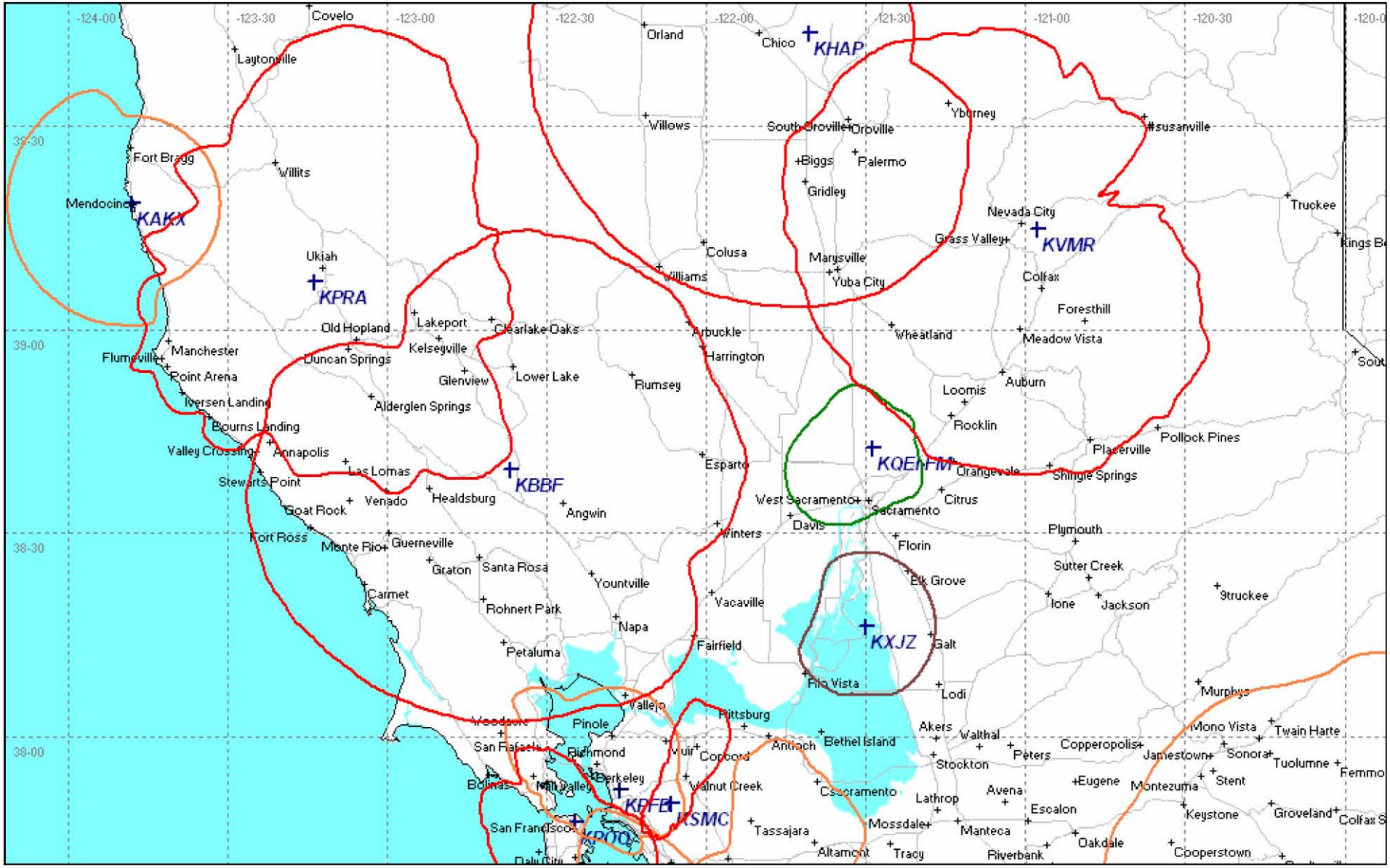

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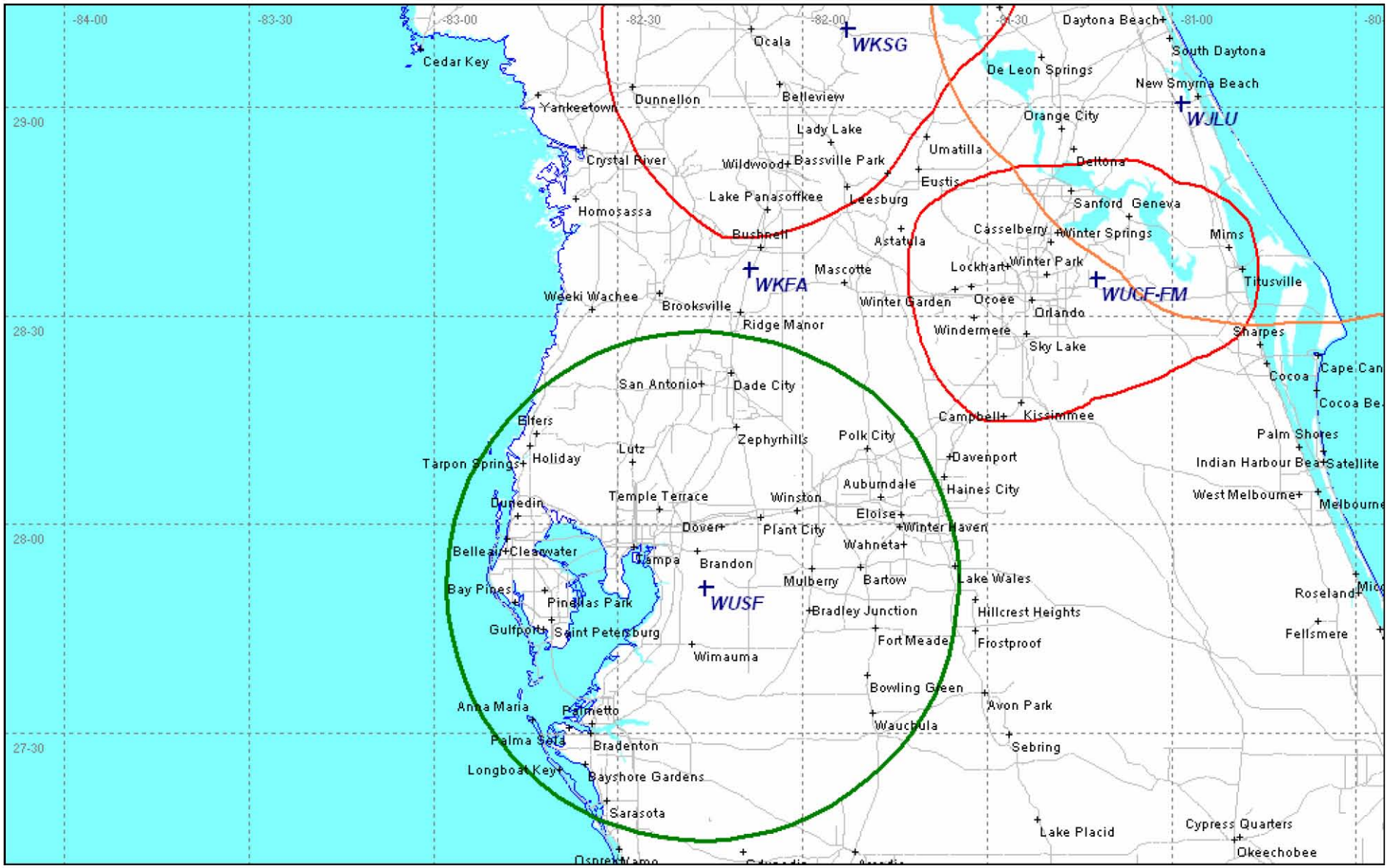

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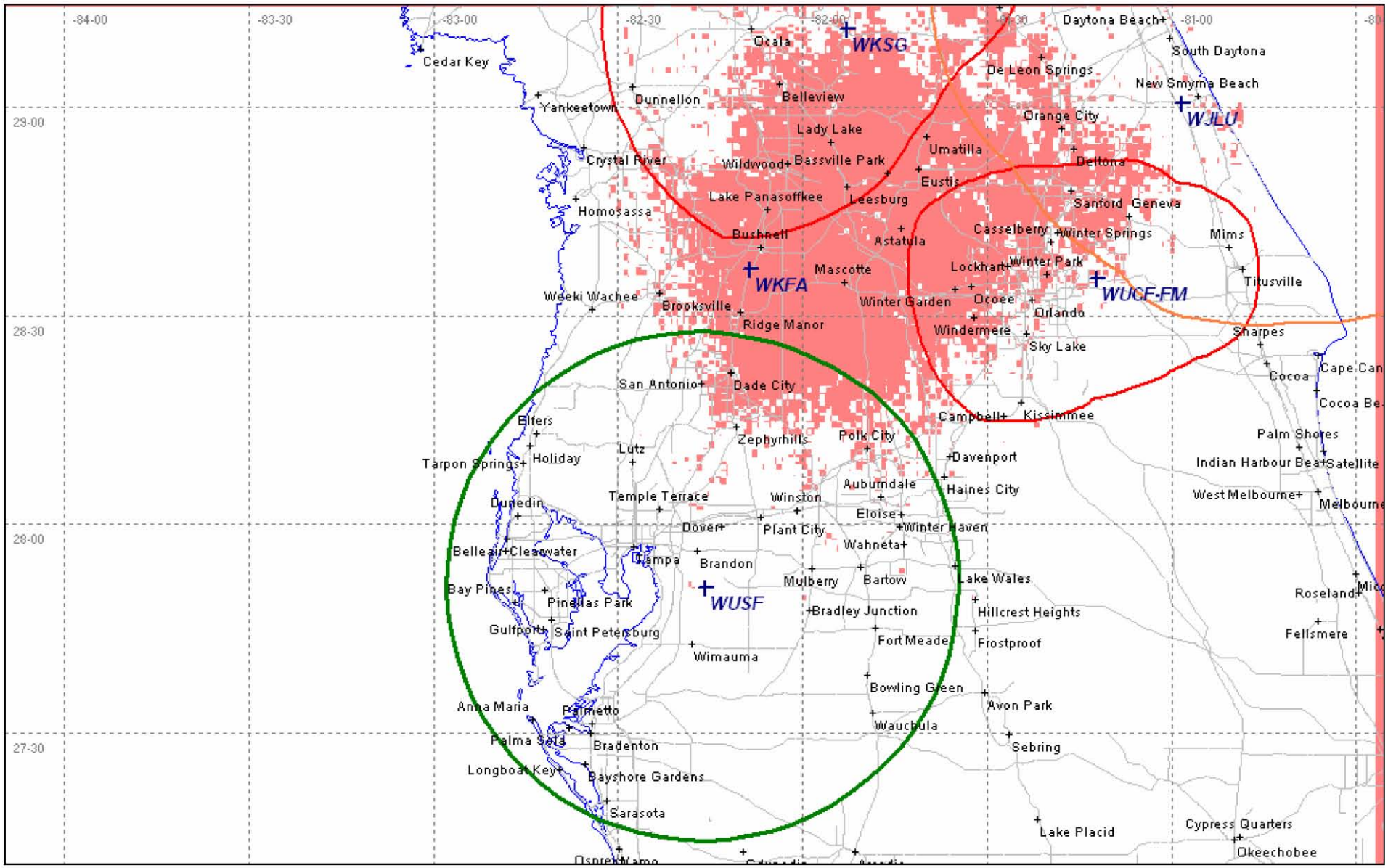

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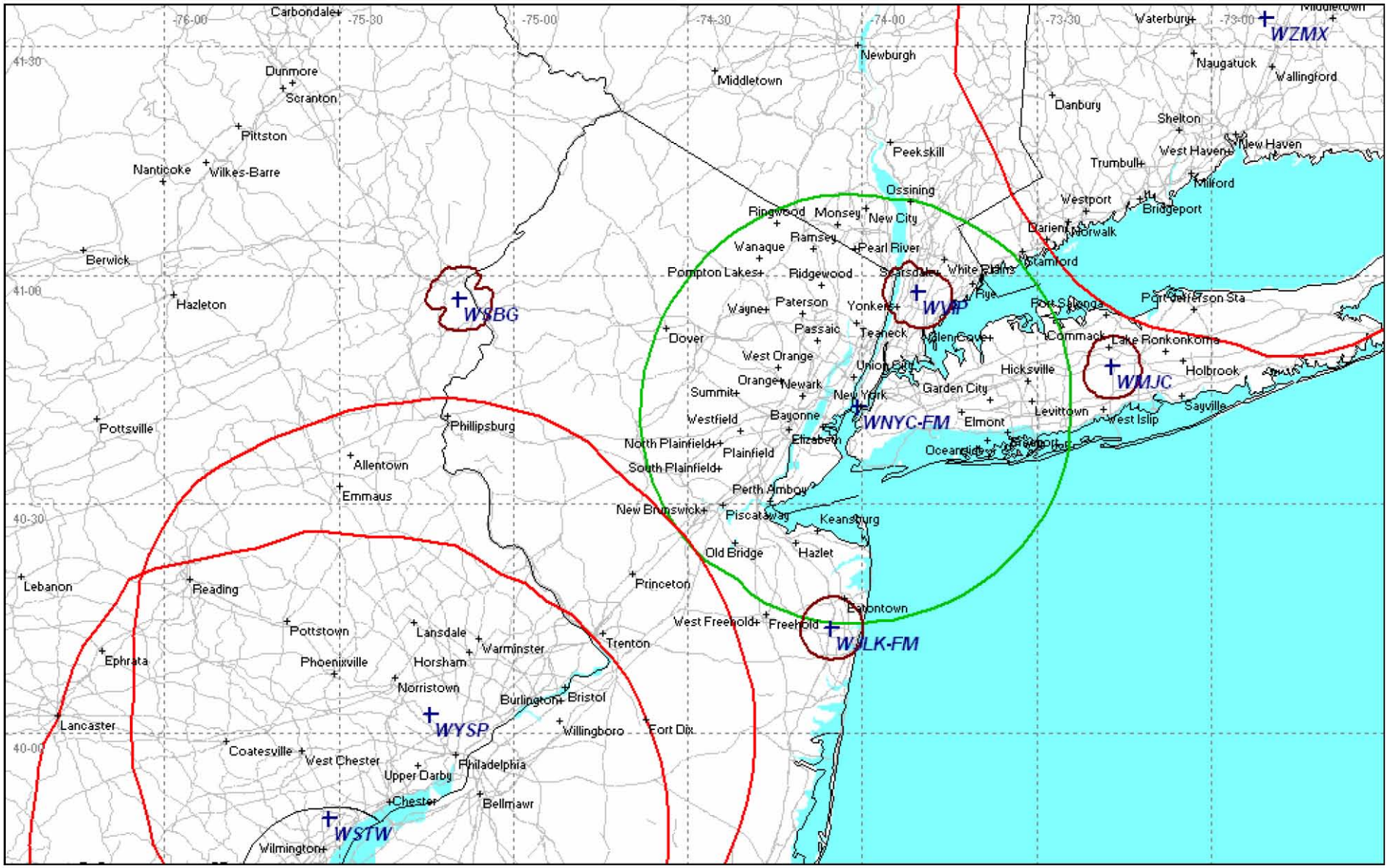

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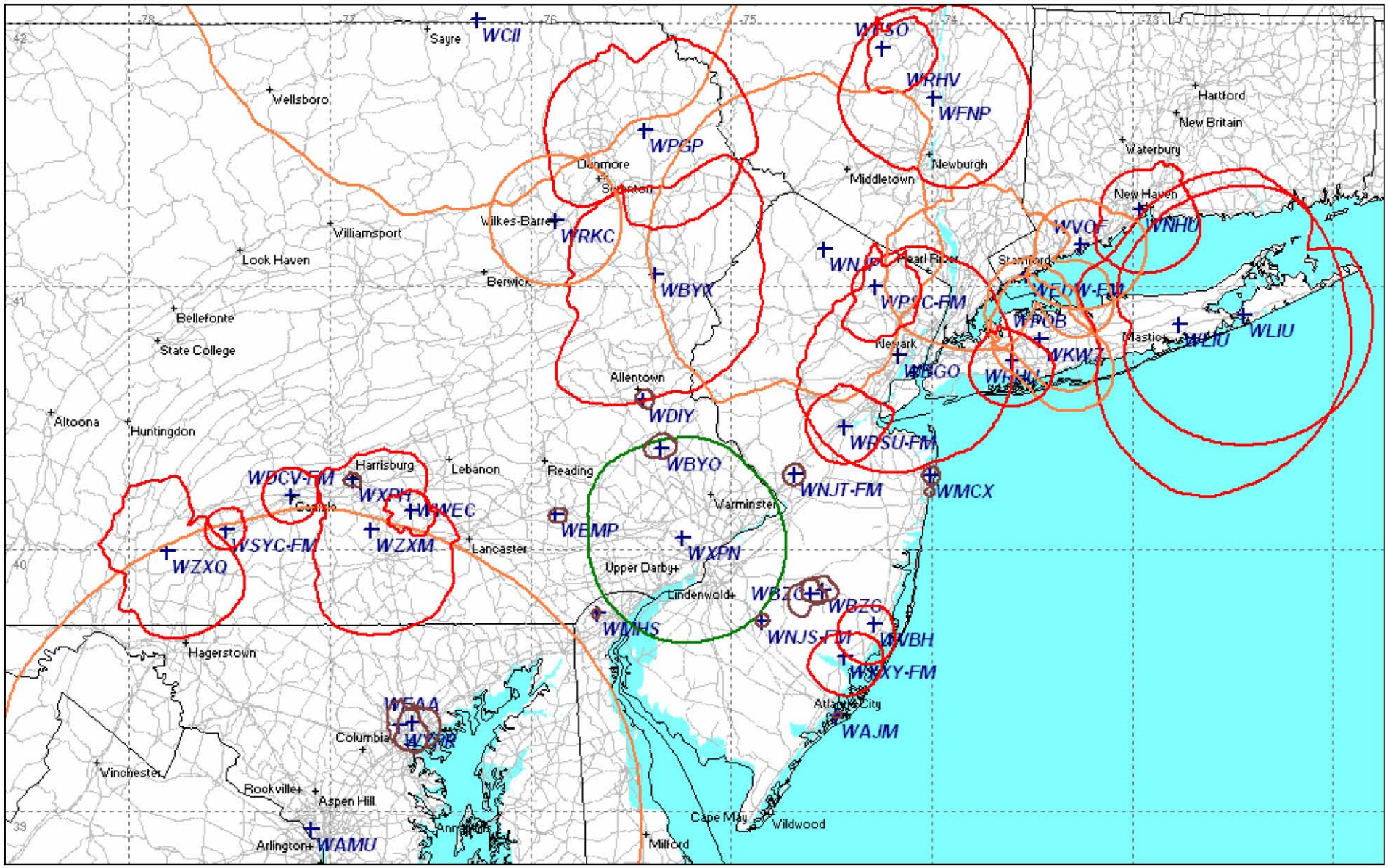

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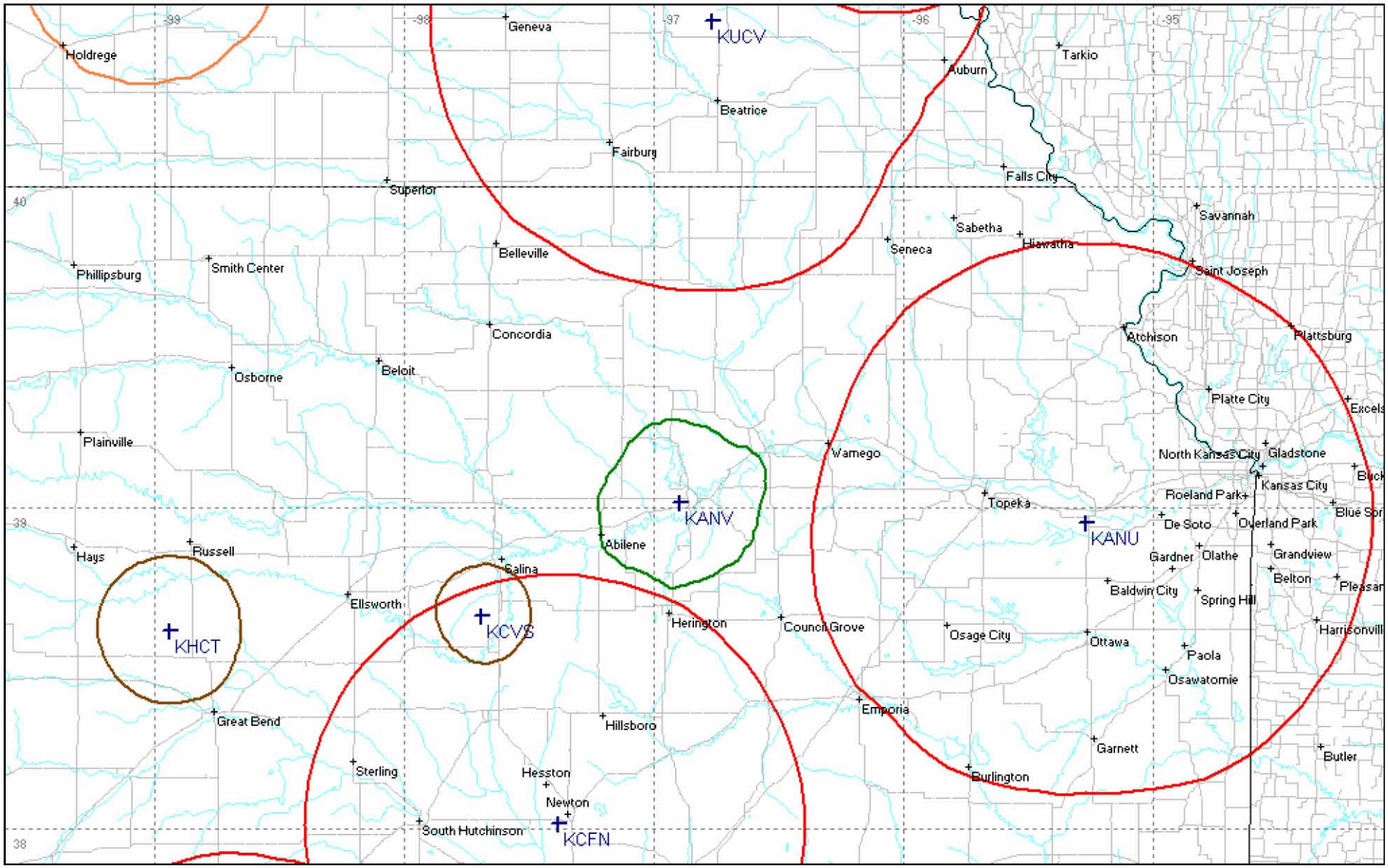
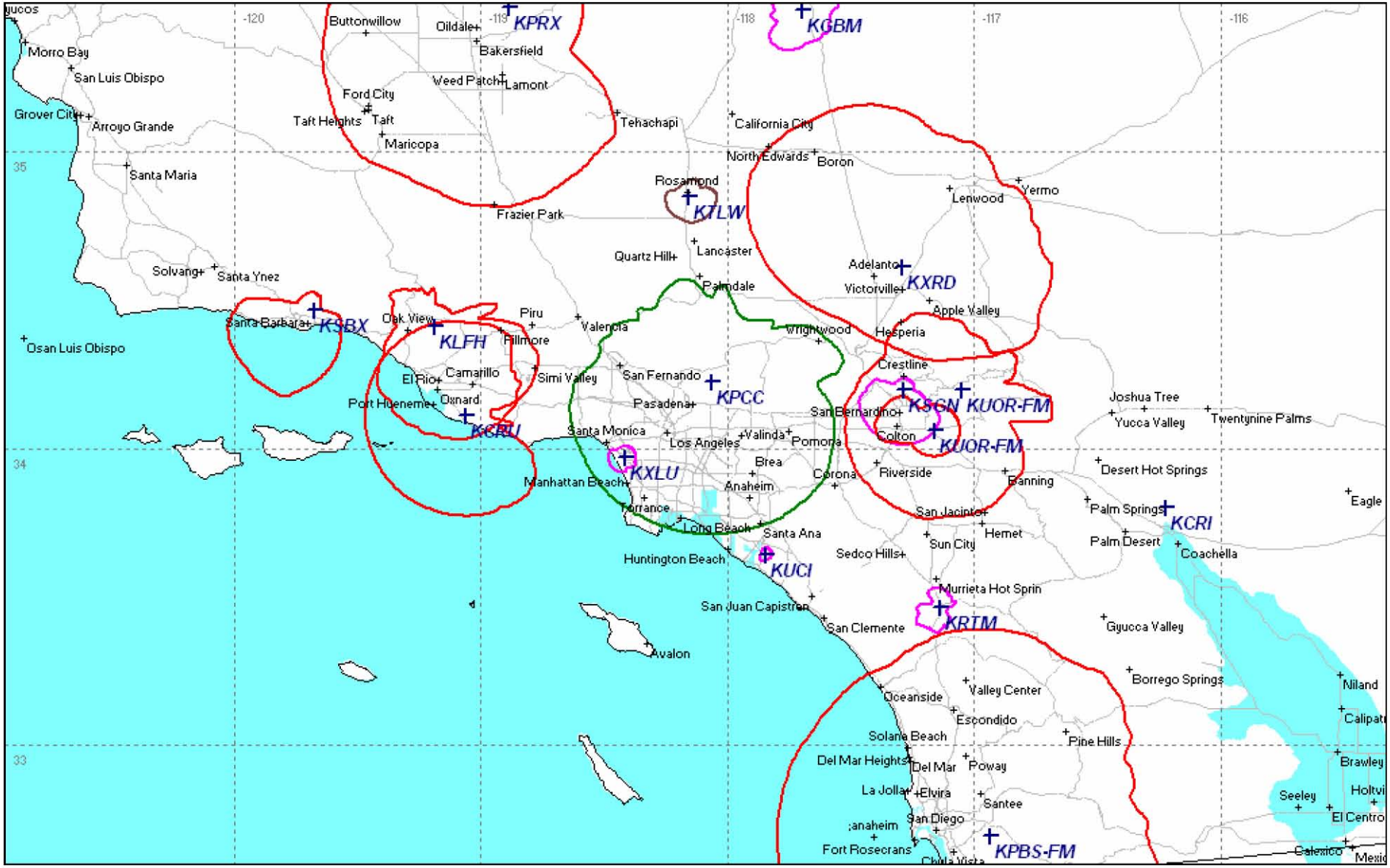


Appendix D - MAPS OF 10 CANDIDATE-STATIONS SELECTED FOR MEASUREMENT



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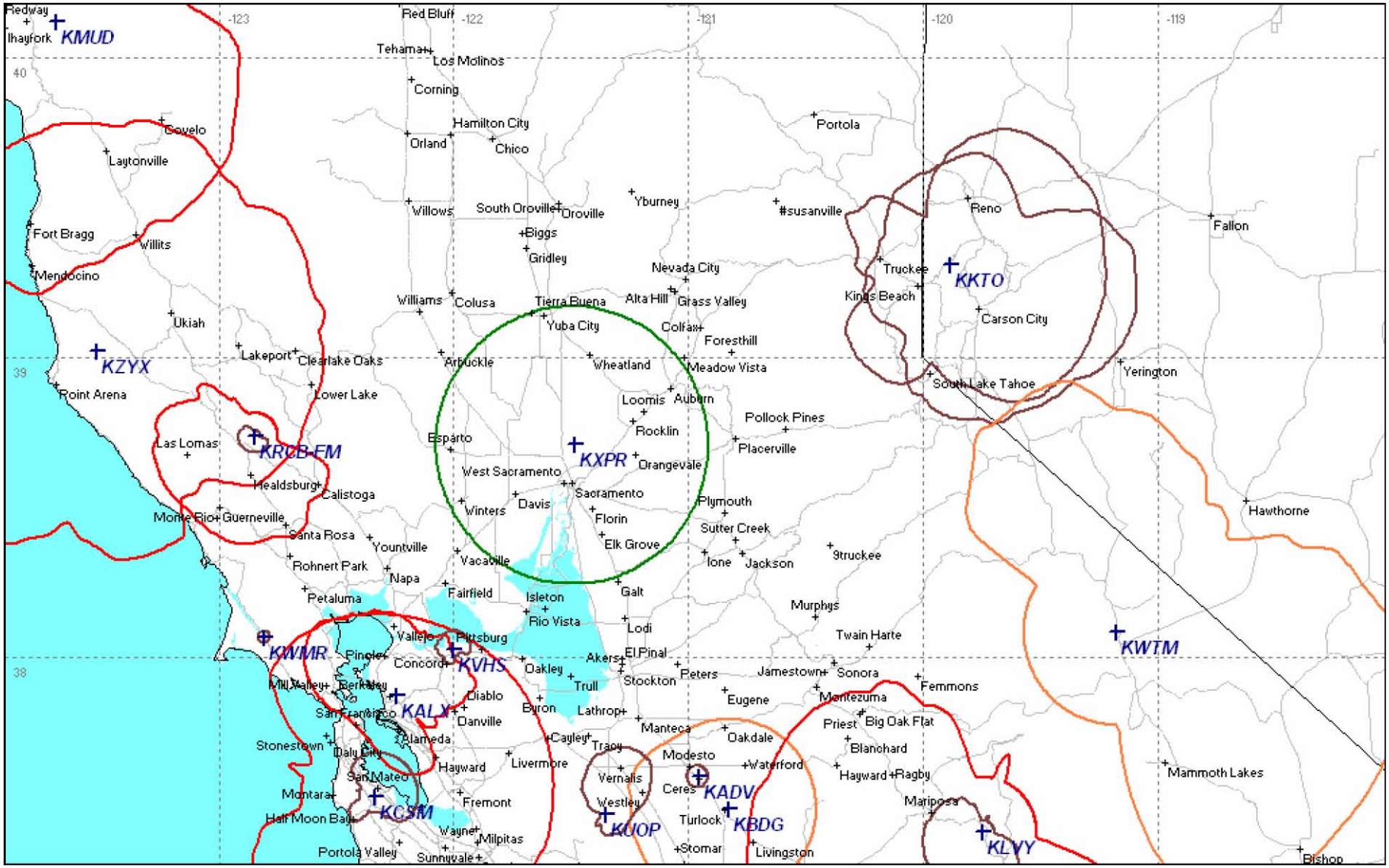

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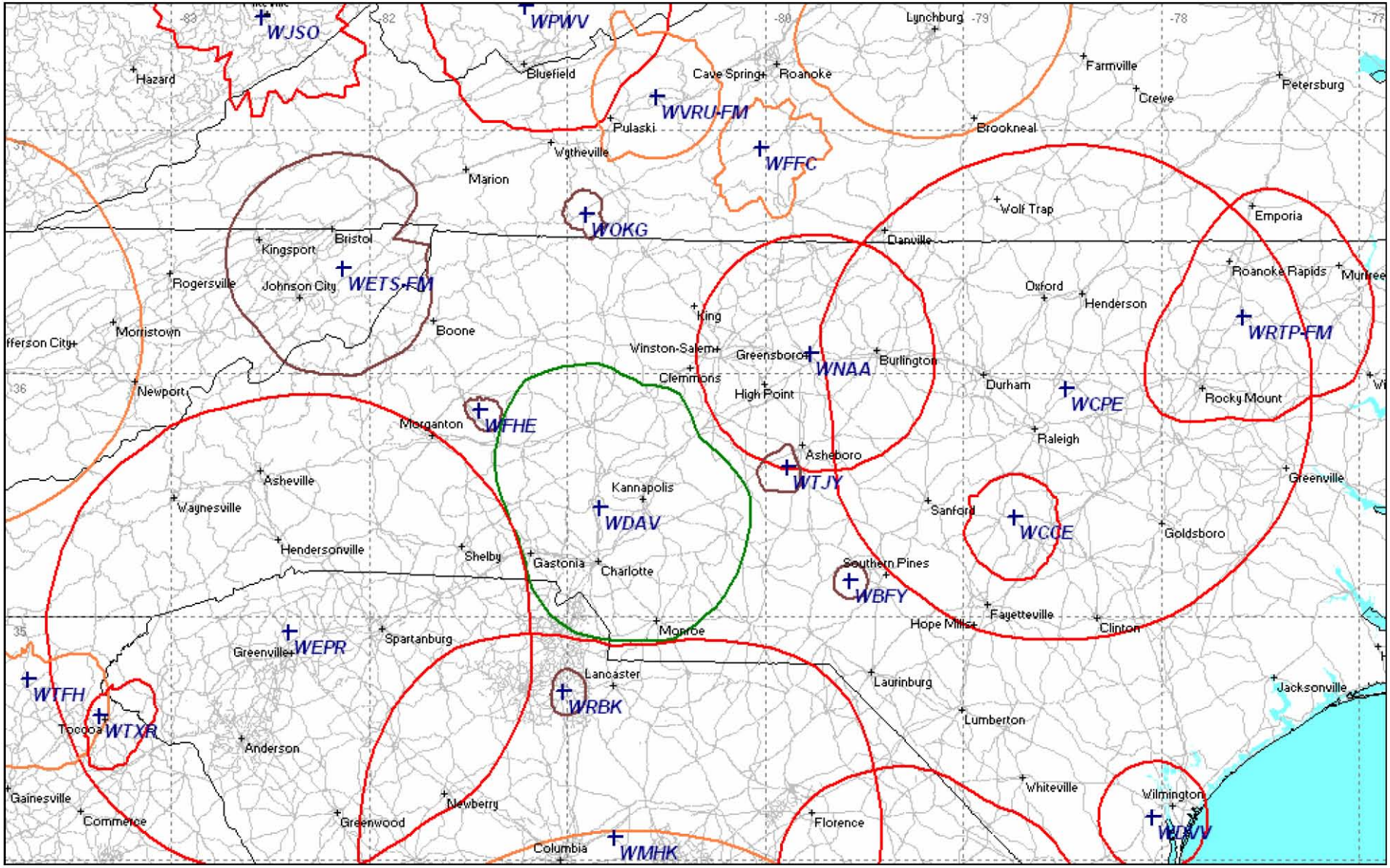
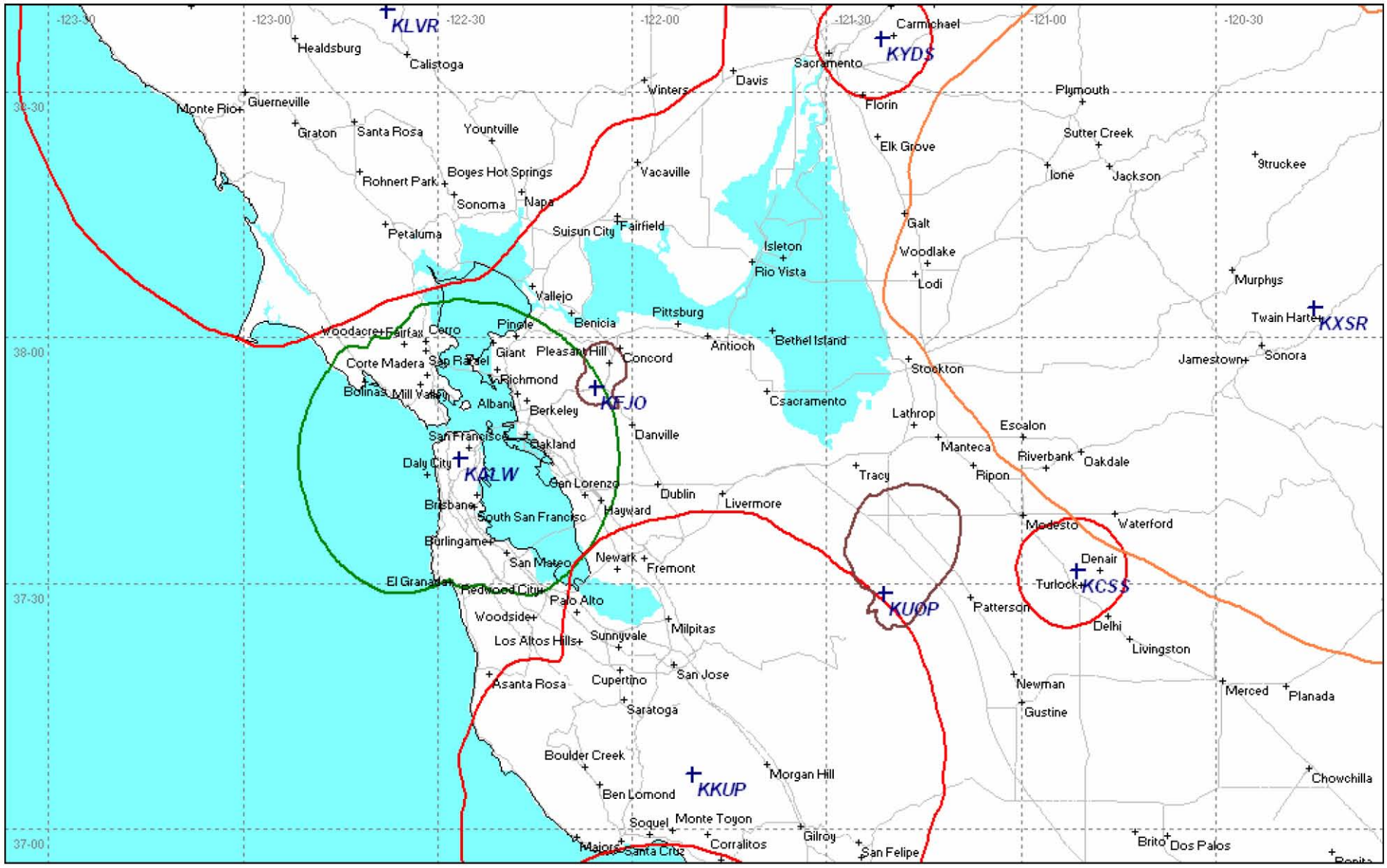


Appendix D - MAPS OF 10 CANDIDATE-STATIONS SELECTED FOR MEASUREMENT



NATIONAL PUBLIC RADIO

Report to the Corporation for Public Broadcasting

Digital Radio Coverage & Interference Analysis (DRCIA) Project:
Interim Report #2
Deliverables 3.1, 3.2, 3.3, and 3.4

CPB Account No. 10446
Reporting Period: November 1, 2006 through January 31, 2007

INTRODUCTION

NPR is pleased to present the Corporation for Public Broadcasting this second report on the Digital Radio Coverage and Interference Analysis project. This update reviews NPR's selection of stations needed for market studies (as revised from the first report), the selection of the RF planning tools used for coverage mapping, and the RF Test Bed for receiver measurements. A financial report covering the 11/01/2006 through 1/31/2007 period will be sent under separate cover.

NPR'S ACTIVITIES DURING PROJECT PERIOD #2 (DELIVERABLE 3.1)

Final Selections For Stations In Largest Radio Markets

In our first report, NPR detailed the rationale behind the selection of markets and stations for consideration in the DRCIA project, and listed our preliminary selections for both large and small market stations (re: contract Deliverable 2.2). We subsequently refined our initial list for the largest markets to reflect a greater correlation between stations and the markets they serve.

We ran contour studies of each station in the original list, and affirmed that their 50dBu or .5 mV/m (for FM and AM, respectively) contour intersected some point on the city boundary. The earlier method had taken into account only the much larger Arbitron boundary, which in some instances allowed the inclusion of stations that did not serve the main concentration of population. The refinement offers a fairer selection of stations serving the 50 largest markets. With further consultation with CPB Radio Digital Grants Manager Brian Gibbons, we have reviewed and finalized the list of stations under consideration in the project (the finalized station list for the 50 largest markets can be found in Appendix A).

RF Coverage Software Selection Process

Over the last several months, we have also selected a software engine that we will modify to calculate the various analyses and predictions associated with this study. The process of selecting a software engine involved writing and distributing targeted RFQs to companies currently producing similar products. We evaluated several bids for this customized software, and in the end were left to decide between COVLAB, a program produced by the Communication Research Centre in Canada, and the Communication Systems Planning Tool (CSPT), a program from the Institute for Telecommunication Sciences (ITS) in Boulder, Colorado. The ITS is a part of the US Department of Commerce's National Telecommunications and Information Administration. The ITS is widely recognized as the country's leading research center in signal propagation science and was identified in NPR's original DRCIA proposal to CPB as a project technology partner.

After evaluating the offers, we decided on pursuing development with ITS, and modifying their CSPT program to fulfill the project goals. The CSPT program runs as a free module under ESRI's ArcGIS platform, the most widely used geographic information system (GIS) program. In addition to the large

user base, the ITS is willing to contract with us to customize the CSPT program to include interference modeling, automated operation, and any other needs that arise during the specification process. While the CSPT module is, as stated previously, free, there will be costs associated with customizing the program. Sufficient funds have been allotted within the project to allow for the development of the necessary modifications.

Meetings with Industry Participants
During the current reporting period, NPR project leaders Mike Starling and John Kean met with key officials at the Institute for Telecommunications Sciences, in Boulder, Colorado, including Dr. William Kissick, the Division Chief. As finalized in these discussions, ITS will provide expert peer review on key technical issues in addition to working with NPR in the customization of the CSPT mapping software described earlier. They will also work with us in the calibration of NPR Labs' field measurement antenna at the ITS test range at Table Mountain, just outside Boulder.

To develop an improved field strength antenna for vehicular measurement, NPR labs selected Kintronic Labs of Bristol, Tennessee. Kintronic has designed and constructed antenna systems for broadcasters for decades and is experienced in computer modeling of antennas to optimize the design. The finished antenna will be delivered to the ITS and mounted on an actual test vehicle for tuning and calibration at the Table Mountain Test Range.

STATUS OF FIELD MEASUREMENTS (DELIVERABLE 3.2)

The process of selecting the most appropriate software and hardware for the assembly of our RF testbed (see below) has resulted in a delay of the commencement of station field measurements outlined in Contract Deliverable 3.2. Furthermore, the additional time needed for finalizing the list of stations to be surveyed has further pushed back the start of our field activities. With receiver performance measurements and completion of the field test apparatus scheduled for the first quarter of 2007, field measurements of the stations are now expected to be held in May and June.

STATUS OF ANALYSIS OF IBOC TRANSMISSION SYSTEMS (DELIVERABLE 3.3)

Given the delays in the selection of stations and the development of the field measurement equipment, analysis of IBOC transmission systems of the stations described in Contract Deliverable 3.3 will now follow the start of field measurement activities in May. While these delays have impacted our ability to proceed at the pace we would like, we remain confident that the delivery of subsequent deliverables such as the delivery of our analog and IBOC receiver performance reports and the development of the interference free coverage maps will not be affected.

STATUS OF RECEIVER MEASUREMENT ACTIVITIES (DELIVERABLE 3.4)

As part of the DRCIA Project, NPR Labs will conduct the most comprehensive measurement of FM and AM receivers on record, both in terms of the number of receivers and, more importantly, the number of performance parameters that will be collected. At least 40 receivers are scheduled to be tested, including both analog and analog-HD Radio (hybrid) types. We intend to measure scores of different values for each receiver, including sensitivity, interference susceptibility from analog and hybrid sources, and performance under conditions of impairment such as broadband noise, Rayleigh fading and multipath.

The result will produce a large database for the development of NPR Labs' interference-free coverage models.

The measurement of receiver performance requires a large number of test instruments, assembled into a system referred to as the RF Testbed. NPR Labs has been evaluating and adding to its test instrumentation, as required, to perform the receiver measurements. A diagram of the Test Bed is included as Appendix B. This diagram shows the desired channel signal generators in the lower left, comprising a Boonton FM generator and Harris Dexstar IBOC DAB exciter. Two undesired-channel systems are available, each using a Hewlett-Packard FM generator and Dexstar exciter, to perform single- and double-interferer testing. Due to the large number of interference combinations, we have constructed a General Purpose Interface Bus (GPIB)-based instrumentation remote control and developed MATLAB programming running on a central PC.

To test radios with better interference rejection, such as most car radios, higher levels of signal are required than can be provided by the signal generators. To remedy this, NPR Labs has purchased and built booster amplifiers and GPIB-controlled RF attenuator sets to support wide dynamic range interference tests.

The receiver under test is connected to a Hewlett-Packard audio analyzer, which will measure audio noise using a frequency-weighted quasi-peak characteristic that resembles the ear's response to low-level noise and static. This analyzer sends its readings to the MatLab PC via GPIB connection for storage and later analysis. Other instrumentation may be added to the test bed, such as a broadband noise generator and RF Channel Simulator to produce real-world types of signal impairments. Measurement data on these conditions will be tested and reported later to CPB. If representatives from CPB or its contractors would like to observe testing activities, we would be pleased to arrange a visit.

Appendix A – CPB-Qualified Stations Selected for 50 Largest Markets

Call Sign	Community of License	State	Arbitron Market	CPB Mkt. Rank	CPB Market Name
WBAI	New York	NY	New York	1	New York
WBGO	Newark	NJ	New York	1	New York
WFUV	New York	NY	New York	1	New York
WFUV2	New York	NY	New York	1	New York
WNYC	New York	NY	New York	1	New York
WFMU	Jersey City, NJ	NJ	New York	1	New York
WNYE	New York	NY	New York	1	New York
KCRW	Santa Monica	CA	San Die/Santa B/Los Ang/Bakersfield/Palm Springs	2	Los Angeles
KCSN	Northridge	CA	Los Angeles	2	Los Angeles
KDSC	Thousand Oaks	CA	Santa B/Los Angeles	2	Los Angeles
KKJZ	Long Beach	CA	Los Angeles	2	Los Angeles
KPCC	Pasadena	CA	Los Angeles	2	Los Angeles
KPFK	Los Angeles	CA	Santa B/Los Angeles	2	Los Angeles
KUSC	Los Angeles	CA	San Die/Santa B/Los Angeles/Palm Springs	2	Los Angeles
WHSU-AM	New York	NY	New York	2	New York
WBEZ	Chicago	IL	Chicago	3	Chicago
WDCB	Glen Ellyn	IL	Chicago	3	Chicago
WRTE	Chicago	IL	Chicago	3	Chicago
KALW	San Francisco	CA	San Francisco	4	San Francisco
KPFA	Berkeley	CA	San Fra/Fresno	4	San Francisco
KQED	San Francisco	CA	San Fra/Montere/Sacramento	4	San Francisco
WILL-AM	Chicago	IL	Chicago	4	Chicago
KERA	Dallas	TX	Tyler-L/Dallas-Ft Worth	5	Dallas-Ft. Worth
KNON	Dallas	TX	Dallas-Ft Worth	5	Dallas-Ft. Worth
KPFT	Houston	TX	Waco/Houston-Galveston	6	Houston-Galveston
KPVU	Prairie View	TX	Houston-Galveston	6	Houston-Galveston
KTSU	Houston	TX	Houston-Galveston	6	Houston-Galveston
KUHF	Houston	TX	Houston-Galveston	6	Houston-Galveston
WHYY	Philadelphia	PA	Philade/New York	7	Philadelphia
WRTI	Philadelphia	PA	Wilkes/Salisbu/Phila/Harrisburg-Lebanon-Car	7	Philadelphia
WXPN	Philadelphia	PA	Philade/Harrisb/Baltimore	7	Philadelphia
WAMU	Washington	DC	Washing/Richmon/Harrisb/Baltimore	8	Washington

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Call Sign	Community of License	State	Arbitron Market	CPB Mkt. Rank	CPB Market Name
WETA	Washington	DC	Washing/Baltimore	8	Washington
WPFW	Washington	DC	Washington DC	8	Washington
WABE	Atlanta	GA	Atlanta	9	Atlanta
WCLK	Atlanta	GA	Atlanta	9	Atlanta
WRFG	Atlanta	GA	Atlanta	9	Atlanta
WDET	Detroit	MI	Detroit	10	Detroit
WEMU	Ypsilanti	MI	Detroit	10	Detroit
WFUM	Flint	MI	Saginaw/Lansing/Detroit	10	Detroit
WKAR	East Lansing	MI	Saginaw/Lansing/Detroit	10	Detroit
WUOM	Ann Arbor	MI	Saginaw/Lansing/Grand R/Detroit	10	Detroit
WBUR	Boston	MA	Provide/Boston	11	Boston
WGBH	Boston	MA	Springf/Provide/Hartfor/Boston	11	Boston
WICN	Worcester	MA	Boston	11	Boston
WKAR-AM	East Lansing	MI	Saginaw/Lansing/Grand R/Detroit	11	Detroit
WUMB	Boston	MA	Boston	11	Boston
WDNA	Miami	FL	Miami-Ft Lauderdale-Hollywood	12	Miami-Ft. Lauderdale-
WLRN	Miami	FL	West Pa/Miami-Ft Lauderdale-Hollywood	12	Miami-Ft. Lauderdale-
WRTU	San Juan	PR	Puerto Rico	13	Puerto Rico
WRUO	Mayaguez	PR	Puerto Rico	13	Puerto Rico
KBCS	Bellevue	WA	Seattle-Tacoma	14	Seattle-Tacoma
KEXP	Seattle	WA	Seattle-Tacoma	14	Seattle-Tacoma
KPLU	Tacoma	WA	Seattle-Tacoma	14	Seattle-Tacoma
KSER	Everett	WA	Seattle-Tacoma	14	Seattle-Tacoma
KUOW	Seattle	WA	Seattle-Tacoma	14	Seattle-Tacoma
KBAQ	Phoenix	AZ	Phoenix	15	Phoenix
KJZZ	Phoenix	AZ	Tucson/Phoenix	15	Phoenix
KUAZ-AM	Tucson	AZ	Phoenix	15	Phoenix
KNAI	Phoenix	AZ	Phoenix	15	Phoenix
KBEM	Minneapolis	MN	Minneapolis-St Paul	16	Minneapolis-St. Paul
KFAI	Minneapolis	MN	Minneapolis-St Paul	16	Minneapolis-St. Paul
KGAC	Saint Peter	MN	Minneap/Mankato-New Ulm-St Peter	16	Minneapolis-St. Paul
KCMP	Minneapolis	MN	Minneapolis-St Paul	16	Minneapolis-St. Paul

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Call Sign	Community of License	State	Arbitron Market	CPB Mkt. Rank	CPB Market Name
KMOJ	Minneapolis	MN	Minneapolis-St Paul	16	Minneapolis-St. Paul
KNGA	Saint Peter	MN	Minneap/Mankato-New Ulm-St Peter	16	Minneapolis-St. Paul
KPBS	San Diego	CA	San Die/Los Angeles	17	San Diego
KSDS	San Diego	CA	San Diego	17	San Diego
WLIU	Southampton	NY	New York	18	Nassau-Suffolk (Long
WRLI	Southampton	NY	New York	18	Nassau-Suffolk (Long
WSHU	Fairfield	CT	New Yor/Hartford-NewBritain-Middltwn	18	Nassau-Suffolk (Long
WSUF	Noyack	NY	Provide/New Yor/Hartford-NewBritain-Middltwn	18	Nassau-Suffolk (Long
WUSB	Stony Brook	NY	New York	18	Nassau-Suffolk (Long
WMNF	Tampa	FL	Tampa-St Petersbrg-Clearwater	19	Tampa-St. Petersburg-
WUSF	Tampa	FL	Tampa-S/Orlando/Ft Myers-Naples-MarcoIsland	19	Tampa-St. Petersburg-
KDHX	Saint Louis	MO	St Loui/Marion-Carbondale(SouthernIL)	20	St. Louis
KWMU	Saint Louis	MO	St Loui/Marion-Carbondale(SouthernIL)	20	St. Louis
WSIE	Edwardsville	IL	St Louis	20	St. Louis
WBJC	Baltimore	MD	Washing/Salisbu/Harrisb/Baltimore	21	Baltimore
WEAA	Baltimore	MD	Baltimore	21	Baltimore
WTMD	Towson	MD	Baltimore	21	Baltimore
WYPR	Baltimore	MD	Washing/Baltimore	21	Baltimore
KGNU	Boulder	CO	Denver-Boulder	22	Denver-Boulder
KUNC	Greeley	CO	Denver-Boulder	22	Denver-Boulder
KUVO	Denver	CO	Denver-Boulder	22	Denver-Boulder
KVOD	Denver	CO	Denver-/Colorado Springs	22	Denver-Boulder
KBOO	Portland	OR	Portland OR	23	Portland
KBPS	Portland	OR	Portland OR	23	Portland
KGNU-AM	Boulder	CO	Denver-Boulder	23	Denver-Boulder
KMHD	Gresham	OR	Portland OR	23	Portland
KOPB	Portland	OR	Portlan/Eugene-Springfield	23	Portland
KOAC-AM	Corvallis	OR	Portlan/Eugene-Springfield	24	Portland
WVPM	Morgantown	WV	Pittsburgh PA/Morgantown	24	Pittsburgh
WDUQ	Pittsburgh	PA	Pittsburgh PA	24	Pittsburgh
WQED	Pittsburgh	PA	Pittsbu/Altoona	24	Pittsburgh
WVNP	Wheeling	WV	Pittsburgh PA/Wheeling	24	Pittsburgh
WYEP	Pittsburgh	PA	Pittsburgh PA	24	Pittsburgh

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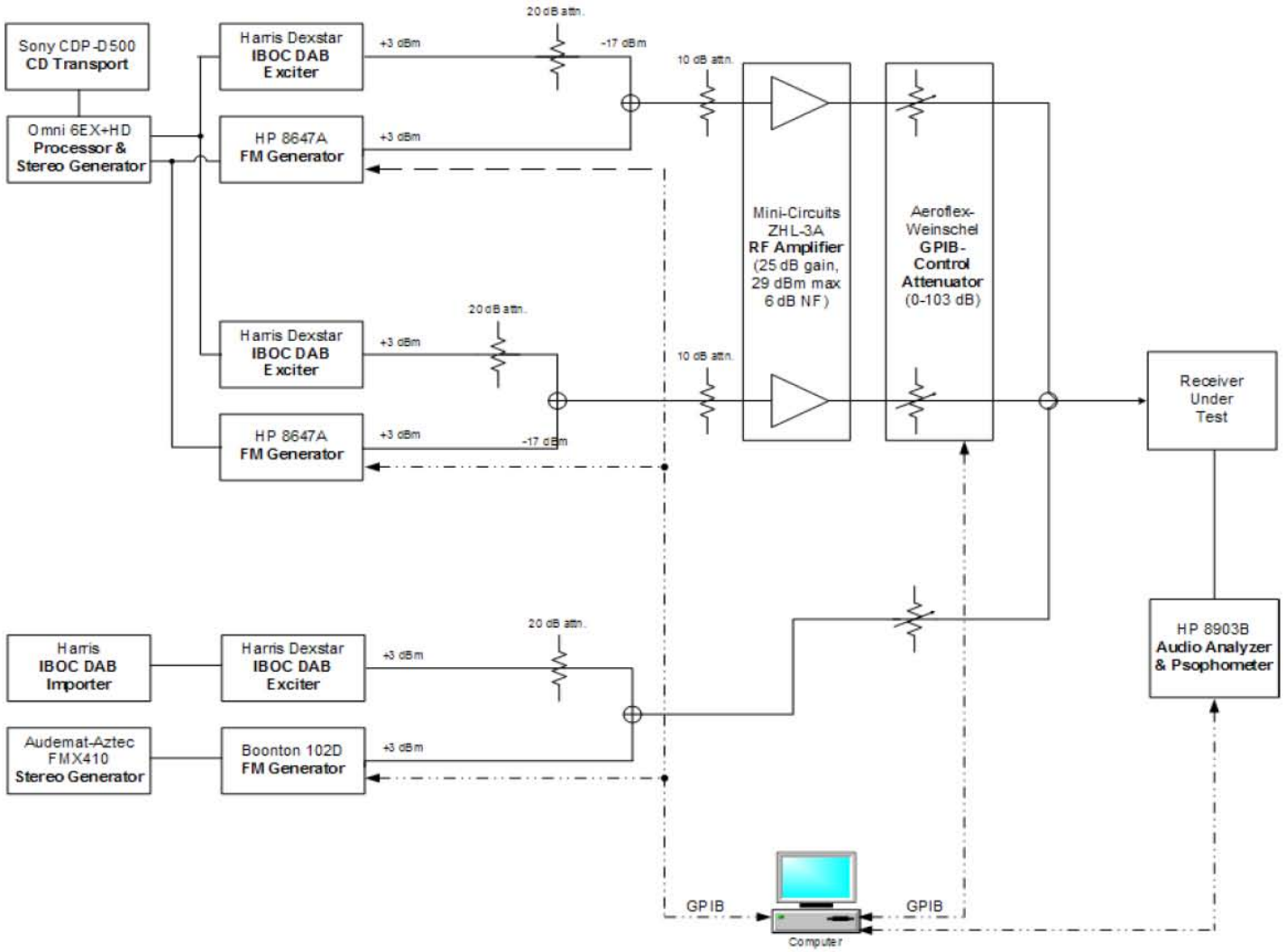
Call Sign	Community of License	State	Arbitron Market	CPB Mkt. Rank	CPB Market Name
KVCR	San Bernardino	CA	Los Angeles	25	Riverside-San Bernardino
WCPN	Cleveland	OH	Cleveland	26	Cleveland
WKSU	Kent	OH	Youngst/Cleveland	26	Cleveland
KQEI	North Highlands	CA	San Fra/Sacramento	27	Sacramento
KXJZ	Sacramento	CA	San Fra/Sacramento	27	Sacramento
KXPR	Sacramento	CA	San Fra/Sacramento	27	Sacramento
WGUC	Cincinnati	OH	Dayton/Cincinnati	28	Cincinnati
WMUB	Oxford	OH	Dayton/Cincinnati	28	Cincinnati
WNKU	Highland Heights	KY	Cincinnati	28	Cincinnati
WVXU	Cincinnati	OH	Indiana/Dayton/Cincinnati	28	Cincinnati
KPAC	San Antonio	TX	San Antonio	29	San Antonio
KSTX	San Antonio	TX	San Antonio	29	San Antonio
KANU	Lawrence	KS	Topeka/Kansas City	30	Kansas City
KCUR	Kansas City	MO	Kansas City	30	Kansas City
KKFI	Kansas City	MO	Kansas City	30	Kansas City
KTBG	Warrensburg	MO	Springf/Kansas/Columbia MO	30	Kansas City
KBYU	Provo	UT	Salt Lake City-Ogden-Provo	31	Salt Lake City-Ogden-
KCPW	Salt Lake City	UT	Salt Lake City-Ogden-Provo	31	Salt Lake City-Ogden-
KRCL	Salt Lake City	UT	Salt Lake City-Ogden-Provo	31	Salt Lake City-Ogden-
KUER	Salt Lake City	UT	Salt Lake City-Ogden-Provo	31	Salt Lake City-Ogden-
KCEP	Las Vegas	NV	Las Vegas	32	Las Vegas
KCNV	Las Vegas	NV	Las Vegas	32	Las Vegas
KNPR	Las Vegas	NV	Salt La/Las Vegas	32	Las Vegas
KUNV	Las Vegas	NV	Las Vegas	32	Las Vegas
WDAV	Davidson	NC	Charlotte-Gastonia-Rock Hill	33	Charlotte-Gastonia-Rock
WFAE	Charlotte	NC	Greensb/Charlotte-Gastonia-Rock Hill	33	Charlotte-Gastonia-Rock
WNSC	Rock Hill	SC	Greenvi/Columbi/Charlotte-Gastonia-Rock Hill	33	Charlotte-Gastonia-Rock
WMFE	Orlando	FL	Tampa-S/Orlando	34	Orlando
WUCF	Orlando	FL	Orlando	34	Orlando
KCSM	San Mateo	CA	San Francisco	35	San Jose
WHAD	Delafield	WI	Milwauk/Madison/Green Bay	36	Milwaukee-Racine
WUWM	Milwaukee	WI	Milwaukee-Racine	36	Milwaukee-Racine
WYMS	Milwaukee	WI	Milwaukee-Racine	36	Milwaukee-Racine

Appendix A – CPB-Qualified Stations Selected for 50 Largest Markets

Call Sign	Community of License	State	Arbitron Market	CPB Mkt. Rank	CPB Market Name
WCBE	Columbus	OH	Columbus OH	37	Columbus
WHA-AM	Milwaukee	WI	Milwaukee-Racine	37	Milwaukee-Racine
WOSU	Columbus	OH	Dayton/Columbu/Cleveland	37	Columbus
WOSU-AM	Columbus	OH	Dayton/Columbu/Cleveland	37	Columbus
WBAA-AM	West Lafayette	IN	Indianapolis	37	Indianapolis
WFIU	Bloomington	IN	Terre H/Indianapolis	40	Indianapolis
WFYI	Indianapolis	IN	Indianapolis	40	Indianapolis
WHRO	Norfolk	VA	Norfolk-VaBeach-Newport News	41	Norfolk-Virginia Beach-
WHRV	Norfolk	VA	Norfolk-VaBeach-Newport News	41	Norfolk-Virginia Beach-
WNSB	Norfolk	VA	Norfolk-VaBeach-Newport News	41	Norfolk-Virginia Beach-
WRVS	Elizabeth City	NC	Norfolk/Greenville-NewBern-Jacksnvlle	41	Norfolk-Virginia Beach-
KNCT	Killeen	TX	Waco/Dallas-/Austin	42	Austin
KUT	Austin	TX	San Ang/San Ant/Austin	42	Austin
WNCU	Durham	NC	Raleigh-Durham	43	Raleigh-Durham
WSHA	Raleigh	NC	Raleigh-Durham	43	Raleigh-Durham
WFSS	Fayetteville	NC	Wilming/Raleigh/Fayetteville NC	43	Raleigh-Durham
WUNC	Chapel Hill	NC	Raleigh/Norfolk/Greensb/Greenvi/Fayetteville	43	Raleigh-Durham
WMOT	Murfreesboro	TN	Nashville	44	Nashville
WPLN	Nashville	TN	Nashville	44	Nashville
WFDD	Winston-Salem	NC	Greensboro-WnstnSalm-HighPnt	45	Greensboro-Winston-
WQCS	Fort Pierce	FL	West Pa/Orlando	46	West Palm Beach-Boca
WXEL	West Palm Beach	FL	West Pa/Miami-Ft Lauderdale-Hollywood	46	West Palm Beach-Boca
WWIO-AM	St Mary's	GA	Jacksonville	47	Jacksonville
WJCT	Jacksonville	FL	Jacksonville	47	Jacksonville
KCSC	Edmond	OK	Tulsa/Oklahoma City	48	Oklahoma City
KGOU	Norman	OK	Oklahoma City	48	Oklahoma City
KOSU	Stillwater	OK	Tulsa/Oklahoma City	48	Oklahoma City
KROU	Spencer	OK	Oklahoma City	48	Oklahoma City
WKNA	Senatobia	MS	Memphis	49	Memphis
WKNO	Memphis	TN	Memphis/Jackson TN	49	Memphis
WMAV	Oxford	MS	Memphis/Columbus/Tupelo	49	Memphis
WFCR	Amherst	MA	Springf/Hartfor/Boston/Albany-Schenectady-Tro	50	Hartford-New Britain-
WHUS	Storrs	CT	Hartford-NewBritain-Middltwn	50	Hartford-New Britain-
WPKT	Meriden	CT	Provide/New Yor/Hartford-NewBritain-Middltwn	50	Hartford-New Britain-

Appendix B – RF Laboratory Test Bed Interim Diagram



NATIONAL PUBLIC RADIO

Report to the Corporation for Public Broadcasting

Digital Radio Coverage and Interference Analysis (DRCIA) Project: IBOC Radio Receiver Performance Report Deliverable 6.6

CPB Account No. 10446
Reporting Date: July 10, 2007

INTRODUCTION

NPR is pleased to present the Corporation for Public Broadcasting this interim report on IBOC DAB Receiver Performance Tests for the Digital Radio Coverage and Interference Analysis project. This update reviews NPR's design of the measurement Test Bed, the selection of receivers, and preliminary results of the receiver measurements.

NPR'S TESTING OF IBOC DAB RECEIVERS (DELIVERABLE 6.6)

Selections for Receivers

NPR Labs selected receivers for automobile and tabletop (indoor) applications. Portables are not yet available due to the high power requirements of current chip sets used in the IBOC receivers. One tested model, the Visteon HD Jump, is "transportable" and can be moved easily between car and home, but requires external power and antenna. Only one automobile receiver is in OEM production, for the high-end BMW car models. This radio is not available for purchase (without the car) and would be challenging to operate since it is integrated into other digital systems in the vehicle.

We sought out models that are in production, as of this report. For example, the Radiosophy HD100 that we own was part of a limited production run and is no longer available to the public. We excluded after-market car radio models we own, made by Alpine, Eclipse, JVC and Panasonic, as they were non-multicast capable products (and are also out of production).

The 15 receivers used for testing are reported in Appendix A: many of these receivers are pictured and described in Appendix D, which is an NPR Labs report to the system in May, 2007. While these selections span a considerable range of cost, most share a common iBiquity-designed model #1181 tuner board, which performs the functions of RF amplification and IF down-conversion, IF filtering, and IBOC data decoding/audio decoding using a Texas Instruments DSP chip. With these tuner boards, only the RF/IF module tends to change. The RF/IF modules are made by Alps, Samsung, LG and others, but are also relatively similar. The JVC KD-HDR1 after-market car radio uses a Phillips DSP chipset, but performs similarly to other radios with TI-based signal processors.

RECEIVER TEST BED INSTRUMENTATION

As part of the DRCIA Project, NPR Labs is conducting the most comprehensive measurement of FM and AM receivers on record, both in terms of the number of receivers and, more importantly, the number of performance parameters that are being collected. A total of 55 receivers are in testing, including the 15 hybrid-HD Radio units reported here. Current plans are to measure scores of different values for each

receiver, including sensitivity, interference susceptibility from analog and hybrid sources, and performance under conditions of impairment such as broadband noise, Rayleigh fading and multipath.

The measurement of receiver performance requires a large number of test instruments, assembled into a system shown in the "RF Test Bed" diagram of Appendix B. NPR Labs has been evaluating and adding to its test instrumentation, as required, to perform the receiver measurements. This diagram shows the desired channel signal generators in the lower left, comprising a Hewlett Packard 8647A FM generator and Harris Dexstar IBOC DAB exciter. Two undesired-channel systems are available, each using identical FM generators and Dexstar exciters, to perform single- and double-interferer testing. Due to the large number of interference combinations, we have constructed a General Purpose Interface Bus (GPIB)-based instrumentation remote control and developed MATLAB programming running on a central PC.

To test radios with better interference rejection, such as most car radios, higher levels of signal are required than can be provided by the signal generators. To remedy this, NPR Labs has purchased and built booster amplifiers and GPIB-controlled RF attenuator sets to support wide dynamic range interference tests. These RF signal powers are equivalent to field strengths in the range of 90 to 100 dBu, depending on the efficiency of the receiver's antenna.

For analog receiver measurements, to be reported in our next report, the receivers are connected to a Hewlett-Packard 8903B audio analyzer, which measures audio noise using a frequency-weighted quasi-peak characteristic that resembles the ear's response to low-level noise and static. This analyzer sends its readings to the MATLAB PC via GPIB connection for storage and later analysis.

The instrumentation includes an Additive White Gaussian Noise Generator (AWGN) that produces a controlled level of broadband RF noise to simulate the effect of environmental noise. "Real world" sources of this noise include emissions from electric and electronic appliances, computers, some electric lighting, and car electrical and ignition systems. During NRSC testing, iBiquity Digital asked that AWGN at 30,000 degrees Kelvin be added to all analog compatibility measurements. This level of noise was determined from two consultant studies commissioned by iBiquity to represent the cochannel interference that occurs around FM stations. Its purpose was to mask part of the noise degradation caused by IBOC, but it is also a fair addition to the Test Bed, which is otherwise almost noiseless.

The Test Bed includes a Hewlett Packard 11759C RF Channel Simulator, to produce real-world types of signal fading impairments, such as Raleigh fading. This type of fading is common to all mobile reception and is essential to understand the IBOC reception performance of automotive radios. The Channel Simulator provides two independent channels for dual-interference testing or combinations of desired channel and undesired channel fading.

A special system for testing receivers under strong undesired signal conditions was researched and developed. The system, call a "Slot Noise Generator" measures receiver sensitivity under receiver-induced intermodulation effects better than systems with only one or two undesired signal generators.[1] As shown in the diagram in Appendix C, this system uses a pair of filters to sharply limit noise spectra each to a bandwidth of 8 MHz, which are then up-converted to FM band frequencies

[1] First-adjacent and second-adjacent interference normally involve only one or two interfering signals, due to the way stations are allocated and protected under FCC rules. In populous areas the FM band may be filled with many other station signals that are strong enough to reduce receiver sensitivity ("desensitization"), potentially requiring many generators to simulate an FM band crowded with numerous strong station signals.

using high-power mixers and local oscillators. The up-converted noise bands are shown in Figure 1, extending from 88 MHz to 96.5 MHz and from 99.5 MHz to 108 MHz. The desired channel at approximately 98 MHz is added mid-way between the two noise bands and the combined desired signal and noise bands are connected to the receiver under test. A standard sensitivity measurement is performed on the receiver and the level of noise on both bands, acting like many out-of-band FM station signals, is increased until the desensitization is detected. The ratio of noise to desired signal at desensitization threshold is a measure of the receiver's RITOIE (receiver-induced third order intermodulation effect) performance. The higher the ratio of noise bands to Desired Channel signal, the better the strong-signal handling capability of a FM receiver.

Figure 1- Noise and Desired Channel spectra from Slot Noise Generator

By using filtered noise bands, instead of discrete carriers, the receiver's RITOIE performance can be objectively measured for all undesired FM frequencies at once. We believe this unique test will quickly determine the performance of receivers and FM preamplifiers. The bandpass filters and high-power mixers have been ordered and are due shortly. NPR Labs will perform the sensitivity tests of all IBOC and analog receivers as soon as possible and report to CPB.

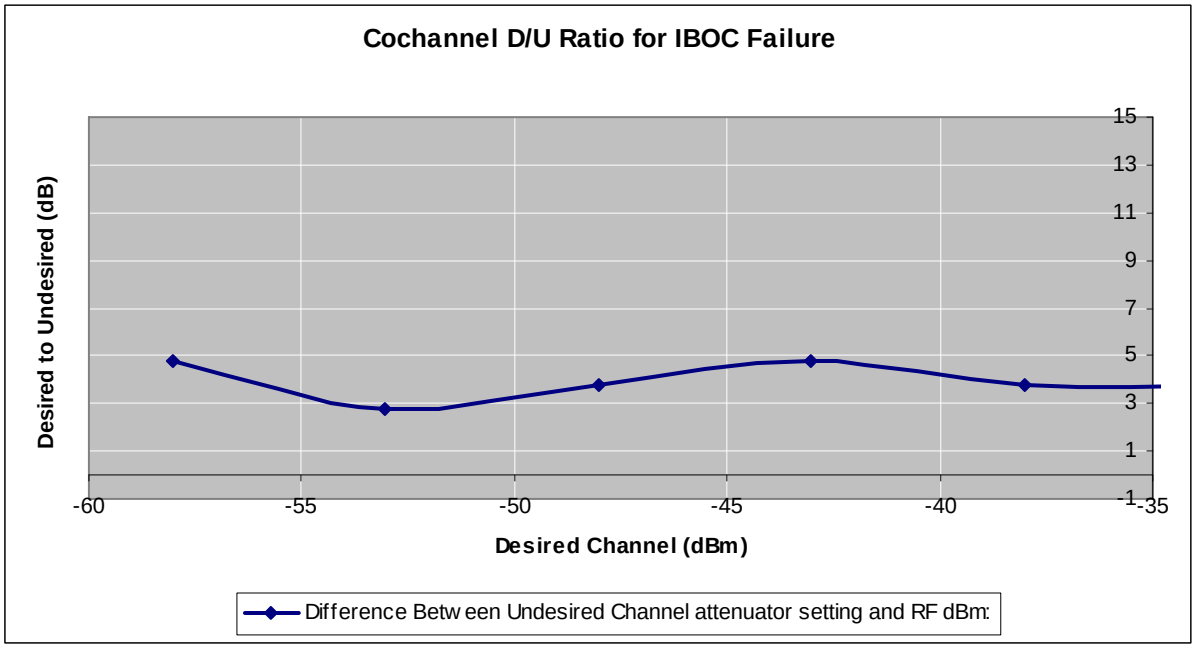
RECEIVER PERFORMANCE MEASUREMENTS

The following data is preliminary as much of it was completed only recently. However, some key findings have emerged that are contributing to the creation of an IBOC DAB coverage prediction model:

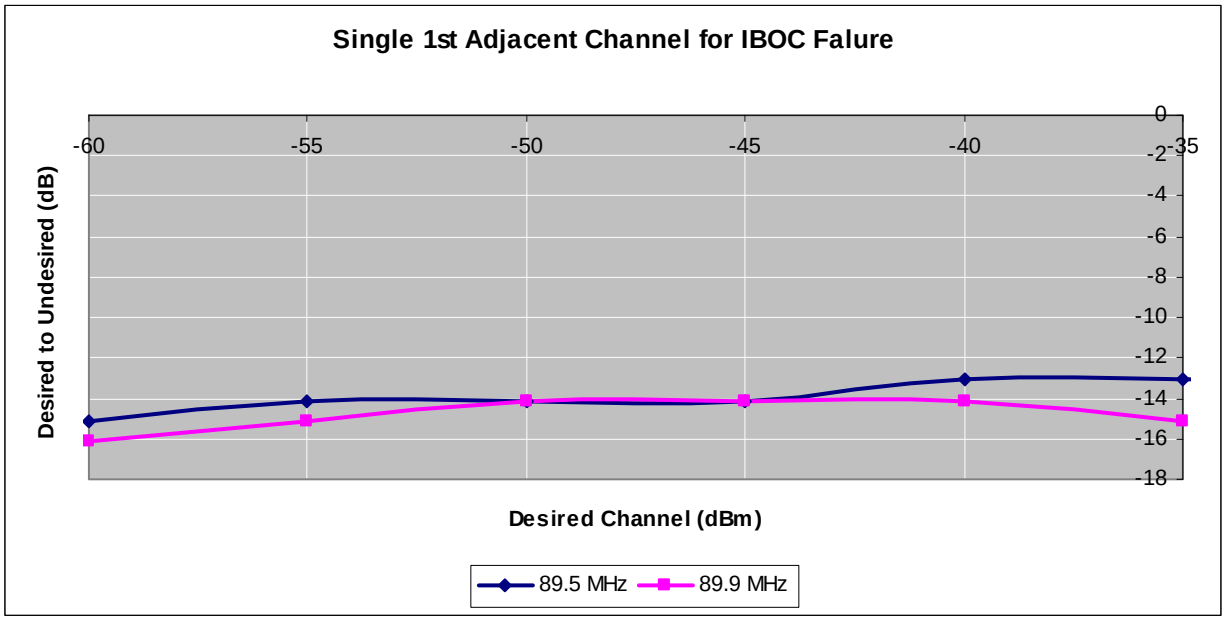
- Receiver sensitivity under interference-free conditions is limited by the level of radiofrequency noise that combines with the desired signal. For example, the best receivers are capable of turning on IBOC reception at a signal power of approximately -89 dBm (expressed in terms of the FM Host carrier when the ratio of IBOC to FM is -20 dB). However, when 30,000°K AWGN is added, the sensitivity drops approximately 10 dB: the Kenwood KTC-HR100 drops to -78.8 dBm, and the Radiosophy HD100, costing $60, drops to –77.8 dBm. This suggests that prediction of IBOC reception, especially indoors, is

strongly affected by environmental RF noise, which varies on a case-by-case basis. This is in addition to other variables, such as receive antenna efficiency and building penetration loss, which are highly variable, as well.

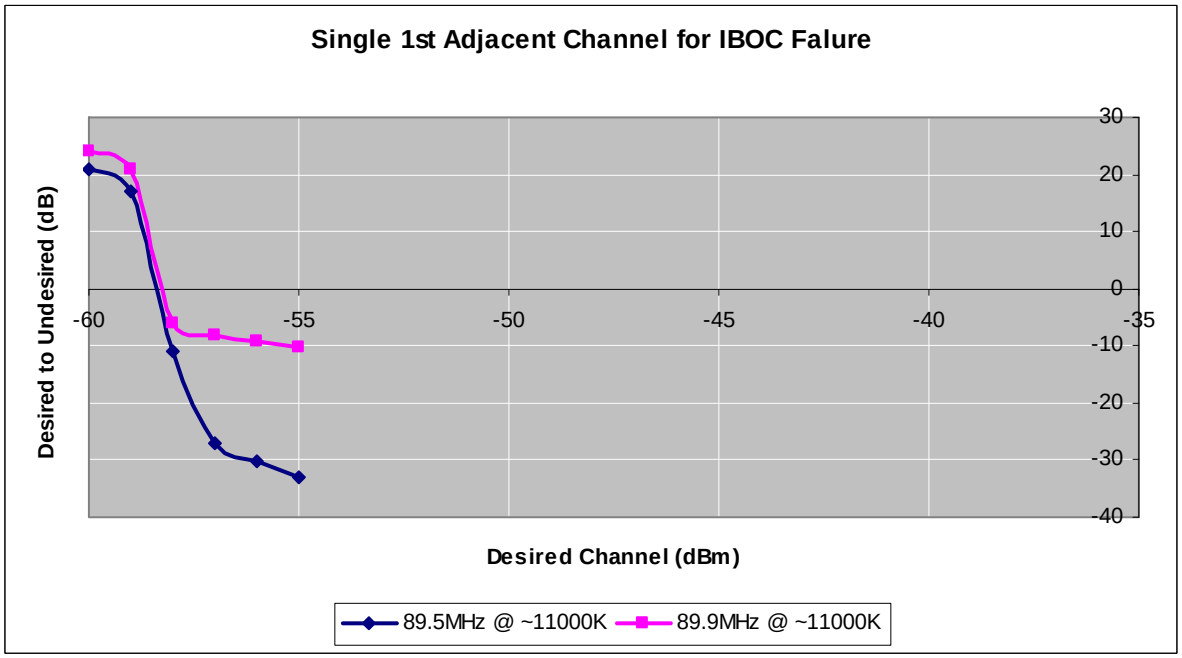
- Cochannel interference susceptibility also appears to be quite uniform among IBOC DAB radios, due to the common use of digital signal processing and similar RF/IF hardware. The susceptibility of the Sangean HDR-1 table radio to cochannel interference is typical of the group. The graph below shows the cochannel D/U (desired-to-undesired) ratio remains around 4 dB, regardless of desired RF input level. (A power of -55 dBm is equivalent to a field strength of approximately 65 dBu with a full dipole antenna.)



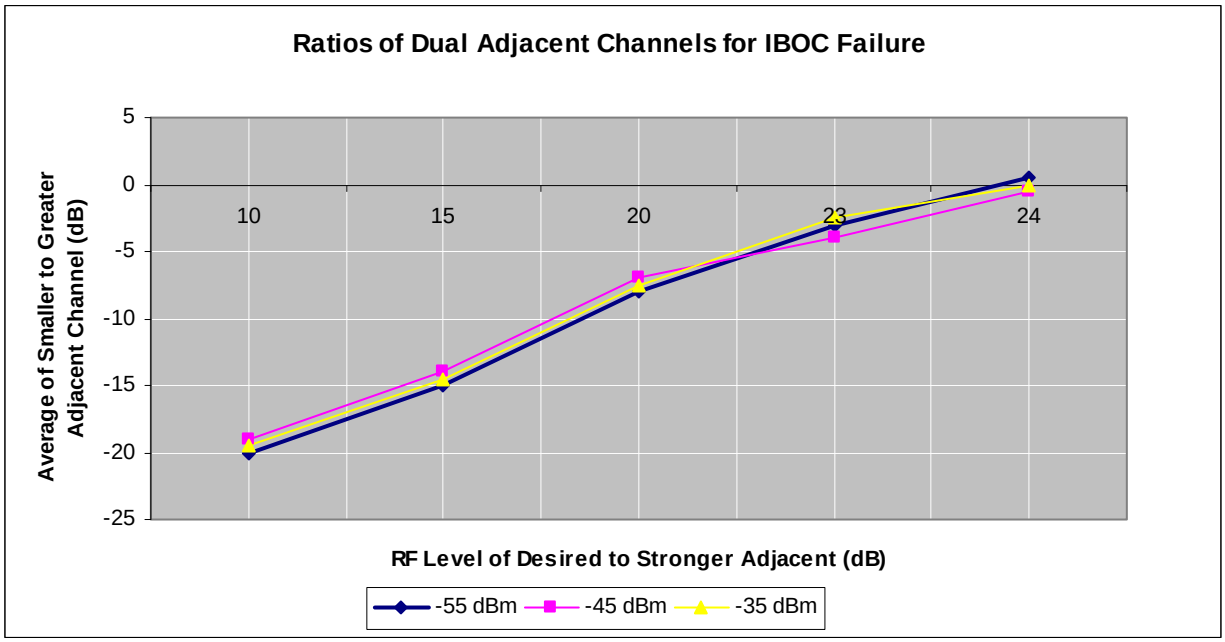
- Single adjacent-channel interference fell into two groups, those that were symmetrical in interference ratio (having equal upper and lower adjacent ratios), and asymmetrical.



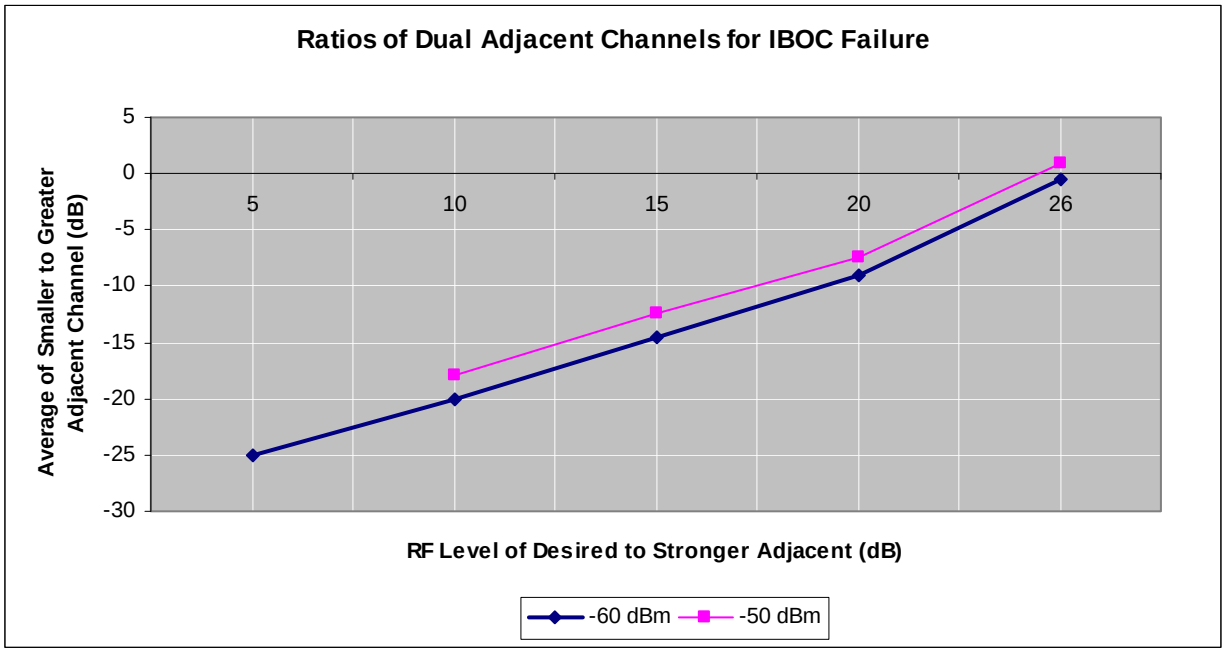
The graph above shows the adjacent-channel susceptibility of the Kenwood tuner averaging close to -14 dB across a wide range of RF power. The Rotel RT1084, an expensive home theater receiver, was an example of the asymmetrical units, providing approximately -10 dB on the upper channel and -30 dB on the lower channel. At least 9 of the 15 receivers exhibited this asymmetry, which could result in significant variations in interference performance, depending on conditions. (The tendencies were not always on the same side of the desired.) This asymmetry indicates poor filter construction or adjustment in the RF/IF tuner.



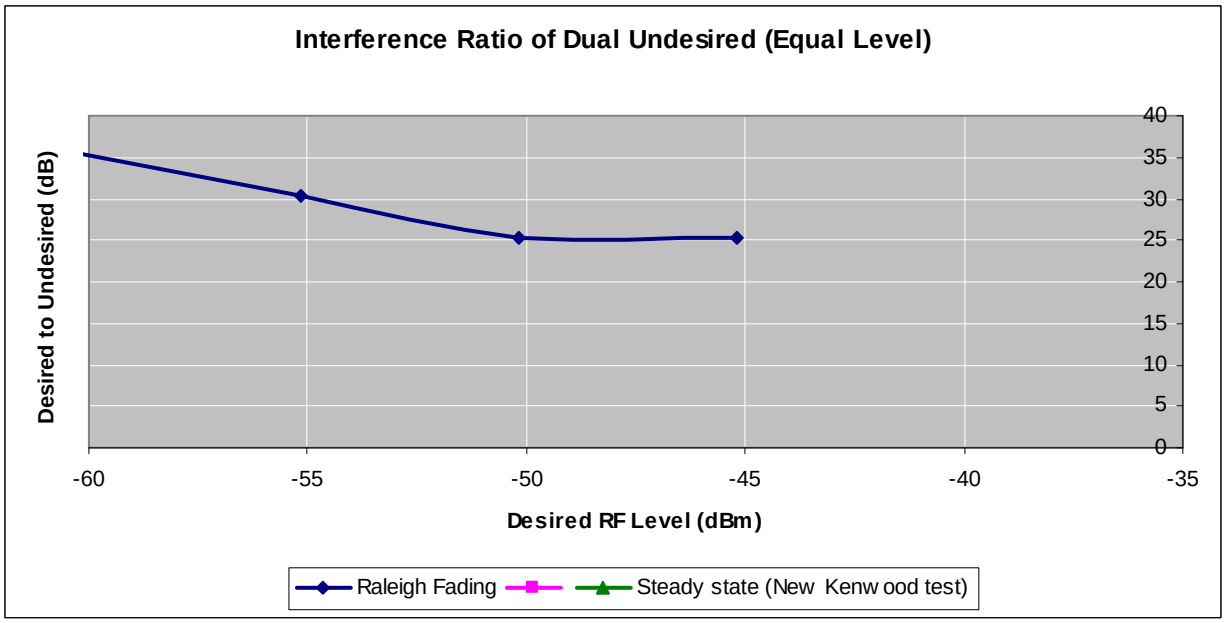
Measurements with dual adjacent channels exhibited similar asymmetry issues, but since these measurements were taken twice, with complementary upper and lower dominant adjacent signals, the asymmetries tended to cancel out. (However, individually, the real interference performance might vary depending on the combination of signal frequencies and levels.) The following graph shows the performance of Sangean HDT-1 home component tuner. This test measured the ratio of the stronger first adjacent to the weaker first adjacent in relation to the ratio of the desired channel signal to the stronger first adjacent channel signal. (While seemingly complex, this measurement is a key to the performance of IBOC receivers in areas where some amount of adjacent interference occurs on both upper and lower channels.) The graph shows that when first-adjacent channel interference is present, it does not take much additional interference from the weaker adjacent channel to cause reception failure.



This condition may be more significant for vehicular reception, where undesired signals may be receivable over large distances. The graph below shows the performance of the Kenwood KTC-HR100 tuner, which NPR Labs uses in its field measurement program. Its performance is slightly better than the rest of the receivers.



- The dual-adjacent channel performance of automobile radios with Rayleigh fading showed an increase in required D/U ratio at lower signal strengths, where these interference conditions may be more likely. The following graph shows the JVC KD-HDR1 with equal first-adjacent undesired ratios (note that the best condition is approximately 25 dB D/U, closely matching the Kenwood above at a 0 dB ratio between the two adjacent channel signals). As the desired channel signal power decreases the required suppression increases by approximately 10 dB at -60 dBm (approximately 60 dBu field strength).



We performed interference tests with hybrid (IBOC) signals as well as analog FM-only signals. Because of the frequency interleaving of the OFDM carrier groups between desired and adjacent channels, direct signal overlap does not occur for the IBOC signal components. The principle source of interference was always the undesired adjacent-channel FM sidebands, which fall directly on the desired channel OFDM carriers, causing signal interference. We performed tests to compare adjacent-channel FM carriers with commercially processed audio to various test tones and found that 1 kHz modulation at 75 kHz peak deviation (100% modulation) compares closely to the processed audio. Because of the constancy of the tone modulation, we performed all tests with 1 kHz modulation on the undesired channels.

We evaluated 2nd and 3rd adjacent channel interference, separately and in combination with 1st-adjacent channel signals. Due to the quality of the RF/IF tuner required by IBOC receivers, the interference from signals separated 400 kHz and 600 kHz was minimal, and above the maximum output power of the Test Bed (90 to 100 dBu equivalent field strength). Since these undesired signals at high levels are not probable at locations at which weak IBOC signals are receivable, 2nd and 3rd adjacent channel interference conditions are a minor effect on IBOC coverage (at least with the present generation of IBOC receivers). No analysis has been conducted of the possible impact on IBOC reception in nearby markets of the cumulative effects of authorizing multiple new third adjacent channel stations within existing stations' service area. Additionally, no study has been conducted on the performance of analog receivers under second and third adjacent conditions as a part of this report. These laboratory measurements should not be projected to allocation rules and interference predictions unless they are confirmed by comprehensive field measurements.

The laboratory data that has been measured for IBOC DAB receivers is now being compared with the field measurements currently being collected. For example, converting the slope and intercept of these measurements into interference prediction formulas indicates good correlation with actual mobile signal measurements, suggesting that it is possible to predict interference-limited IBOC DAB coverage. We look forward to sharing the results of the field measurements with CPB soon and discussing the prediction model development and refinement.

There are some receiver measurements specified in the contract deliverables that were delayed in starting due to the problems uncovered with the commercial field measurement instrumentation, as discussed at our last meeting with CPB. The RITOIE measurements, discussed earlier herein, are being prepared and will be underway shortly. The indoor receive antenna measurements are underway and will be reported soon. However, these will benefit significantly from the new Slot Noise Generator measurement technique, especially for "active" indoor antennas with internal preamplifiers. We detected some cases of receiver-generated digital noise, however, we feel the impact of that effect will be best understood when we complete the coverage prediction model, which is currently being refined by field measurements. We will report on receiver generated noise tests as soon as field measurements are processed. As reported above, the impact on reception of increased IBOC to analog carrier ratio is unlikely to be a consideration for IBOC reception due to the frequency interleaving effect. However, the potential increase in IBOC power will have an impact on analog FM reception, which we have incorporated into our analog test program, currently underway. We look forward to reporting and discussing these results with CPB soon.

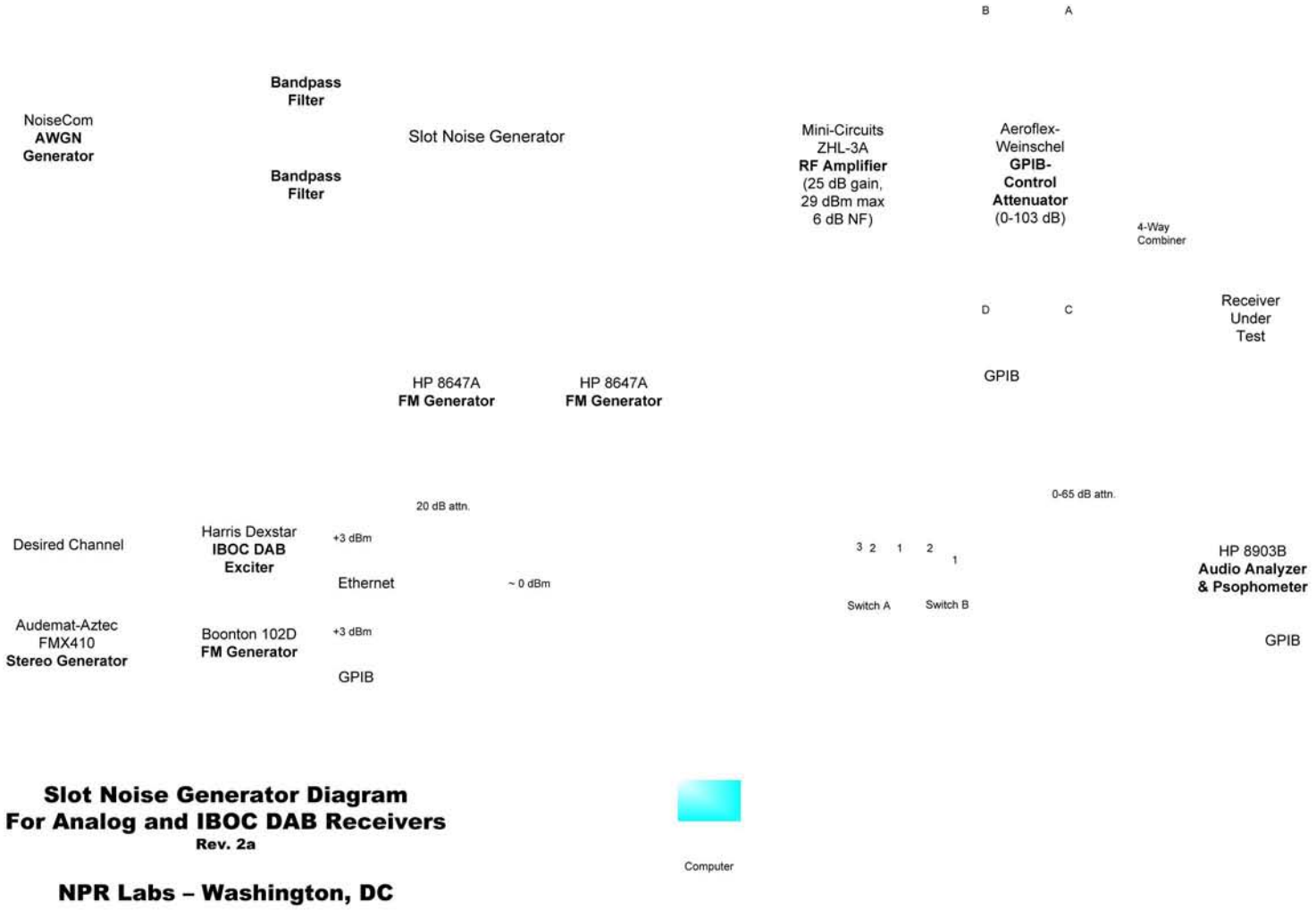
Appendix A – IBOC DAB Tuners and Radios Tested

Category	Brand	Model	Serial No.	date rcvd
auto adapter	AGT/Visteon	HD Zoom HDZ300	KYZ20721000913	20070618
auto after-market	JVC	KD-HDR1	101X0211	20060600
auto after-market	Kenwood	KTC-HR100TR	40400009	2005*
auto/home transportable	AGT/Visteon	HD Jump HDP250	KYJ0716000884	20070618
component tuner	Rotel	RT1084	813-6321192	20070131
component tuner	Sangean	HDT-1	6A012004	20070400
professional	DaySequerra	M2	D70137	2006*
tabletop	AGT/Visteon	HD Pulse HDT200	JH0701900234	20070618
tabletop	Boston Acoustics	HD Recepter	AFQ5D001502	20051100
tabletop	Cambridge SoundWorks	820HD	0049-1307010517	20070621
tabletop	Directed Electronics	DHHD-1000	DH61200003009	20070400
tabletop	Polk	I-Sonic	AM112504261	20061000
tabletop	Radio Shack	Accurian	none	20061000
tabletop	Radiosophy	HD100	n/a	20070707
tabletop	Sangean	HDR-1	6A019569	20070400

* Programming ROM was re-flashed with latest production firmware.

Appendix B – Receiver Test Bed Interim Diagram

Appendix C – Slot Noise Generator for RITOI Measurements



Appendix D

NPR Labs Recommended HD Radio Receivers

May 2007

NPR Labs carefully evaluates many of the currently available HD Radio receivers. In our opinion, these HD Radios represent good values and will please most listeners.

Tabletop HD Radios

Stand-alone, AC-powered radios with built-in loudspeakers and amplifiers

Boston Acoustics HD Recepter

An attractive, compact clock radio. The "satellite loudspeaker" included with the radio adds stereo capability.

Availability (may be limited):

- national web retailers (Amazon.com, Crutchfield.com, J&R.com, etc.) and some audio retailers
- Boston Acoustics website (web link)
- introduced November 2005
- list price: $299.99, discounts offered by some vendors
- a $40 user rebate is available to consumers who purchase a BA HD Recepter radio between 29 April and 3 July 2007; the rebate form can be downloaded.

Features:

- fully Multicast-capable—offers reception of additional HD Radio program channels (HD-2, HD-3); clearly displays availability of Multicast channels
- familiar user controls—rotary knobs for volume and tuning
- presets for 20 stations
- compact, limited-function remote control
- dual alarms, easy to set and use
- second ("stereo") loudspeaker with 10-ft. cable, easy to attach
- dimmable monochrome digital display can show time, station frequency and call-letters with large characters; shows two lines of text of program-related information (PSD) for HD stations, generally regarded as best text display implementation currently available; displays radio data service (RDS) on analog stations (when available)
- extensive tone-control capabilities allows user to "tailor" sound quality
- headphone/line-level output on rear panel (1/8 inch stereo jack)
- auxiliary line-level input on rear panel (1/8 inch stereo jack)
- line-cord mounted "brick" power supply minimizes clutter at wall receptacle
- One year limited warranty

Performance:

- warm, inviting sound quality, will play relatively loudly for a compact radio
- good FM sensitivity, especially when used with supplied external "T" antenna (see "Resources," below); use of the supplied "single wire" FM antenna should be avoided except in areas with very strong signals
- adequate AM sensitivity when supplied external AM antenna is substituted for internal AM antenna

Resources:

- Boston Acoustics website (web link)
- HD Recepter datasheet
- HD Recepter user's manual
- Boston Acoustics' recommendations for improved HD Radio reception

Radio Shack Accurian HD Table Radio

(model/catalog number 12-1686)

A compact, easy to use, one-piece stereo table radio.

Availability:

- Radio Shack stores (nationwide)
- Radio Shack online store
- introduced October 2006
- list price $199.00
- a $40 rebate is available to consumers who purchase an Accurian HD Radio between 29 April and 3 July 2007; the rebate form can be downloaded

Features:

- fully Multicast-capable—offers reception of additional HD Radio program channels (HD-2, HD-3) with indication of Multicast channel availability
- friendly user controls—rotary knob for setting volume; up and down pushbuttons for station selection
- 12 FM and 12 AM presets
- compact, full-function remote control
- two internal speakers offering “one box” stereo reproduction
- monochrome digital display shows time, station frequency and call-letters with large characters; program information (PSD) for HD stations
- five easy-to-select tone control settings
- retains station frequency and frequency presets during brief power outage; time-of-day clock must be reset
- line-cord mounted “brick” power supply minimizes clutter at wall receptacle
- headphone jack (1/8 inch stereo jack) on front of unit
- auxiliary line-level stereo input (1/8 inch stereo jack) on rear panel
- ninety day limited warranty

Performance:

- good sound quality, plays at comfortable volume levels
- good FM sensitivity, especially when used with supplied external "T" antenna; use of supplied "single wire" FM antenna should be avoided except in areas with very strong signals
- good AM sensitivity when used with supplied external AM antenna

Note:

- includes an easy to read clock, but does not offer alarm functions

Resources:

- Radio Shack website (web link)
- Accurian users manual (.PDF file)

Radiosophy HD100 Tabletop Clock Radio

A small, easy-to-use, tabletop stereo clock radio offering low-cost access to HD Radio. Its stylized appearance is reminiscent of "art deco" designs.

Availability:

- Radiosophy online store
- introduced May 2007
- list price $119.95; available at an introductory price of $99.95 through 30 June 2007; users who take advantage of this limited-time offer and the current $40 rebate (see below) can purchase the radio at a net cost of $59.99 plus shipping.
- a $40 rebate is available to consumers who purchase the Radiosophy HD100 between 29 April and 3 July 2007; the rebate form can be downloaded here (.PDF file)

Features:

- fully Multicast-capable—offers reception of additional HD Radio program channels (HD-2, HD-3)
- user friendly user controls—a rotary knob for setting volume; up and down pushbuttons for station selection;

- five pushbuttons for selection of 5 FM and 5 AM user-preset stations
- two internal speakers offer “one box” stereo reproduction
- monochrome digital display shows time, station frequency and call-letters, Multicast channel availability, and program information for HD stations (PSD) and analog stations (RDS)
- built-in telescoping “whip” antenna for FM; external loop antenna for AM
- headphone jack (1/8 inch stereo jack) on front of unit
- auxiliary line-level stereo input (1/8 inch stereo jack) on rear panel
- one-year limited warranty

Performance:

- clear, slightly bright sound quality; plays at comfortable volume levels
- good FM sensitivity when used with the detachable external whip antenna; a standard “F” connector is available for use with external FM antennas
- good AM sensitivity when used with supplied external AM antenna

Notes:

- backlit display can be difficult to read, especially in brightly lit areas; display darkens when radio is off—user can illuminate display by pressing any front panel button
- plug-mounted external power supply may interfere with use of wall receptacles
- signal delivered to the headphone jack is weak but adequate for most headphones

Resources:

- Radiosophy website (web link)
- Radiosophy HD100 User Guide (.PDF file)

Polk I-Sonic HD Table Radio

A one-piece stereo table radio offering very high quality audio performance and many additional features, including CD and DVD-V playback and the ability to add XM satellite radio reception (additional hardware and an annual subscription required for satellite radio service)

Availability:

- Internet retailers and high-end audio stores
- Polk Audio's online store (web link)
- introduced October 2006
- list price $599.00
- a $40 rebate is available to consumers who purchase an I-Sonic HD Radio between 29 April and 3 July 2007; the rebate form can be downloaded here (.PDF file)

Features:

- fully Multicast-capable—offers reception of additional HD Radio program channels (HD-2, HD-3); displays availability of Multicast program channels
- uses push buttons or compact remote control for all functions
- thirty station presets can be selected via menus
- four internal speakers offer impressive "one box" stereo reproduction
- monochrome digital display shows time, station frequency and call-letters with large characters; program information (PSD) for HD stations; RDS text display for analog stations is not supported
- full-function tone controls
- retains station frequency and frequency presets during brief power outage; time-of-day clock must be reset
- headphone jack (1/8 inch stereo jack) on side of unit
- auxiliary connectors on rear of unit include phono jacks for line level audio inputs and outputs, and both composite- and S-Video outputs for DVD video playback
- internal power supply (no external power supply device required)

- one year limited warranty; lifetime customer support available by email and via toll-free telephone numbers

Performance:

- excellent sound quality, can play at room-filling volume levels
- good FM sensitivity, especially when used with supplied external "T" antenna
- good AM sensitivity when used with supplied external AM antenna

Note:

- *some purchasers may find the Polk I-Sonic more complicated to operate than a typical table radio; users should plan on referring to the I-Sonic's owner's manual as they master the unit's many capabilities*

Resources:

- Polk Audio I-Sonic website (web link)
- I-Sonic users manual (.PDF file)

Aftermarket Auto Radios

The installation of car radios can be difficult. Original equipment auto radios are often integrated with other important vehicle systems, such as climate control, navigation assistance, vehicle security systems, etc. We strongly recommend that potential purchasers of aftermarket auto radios thoroughly investigate all issues relating to the replacement or enhancement of the existing radio in their particular vehicle before purchasing an aftermarket HD Radio or HD Radio adapter, and we suggest that buyers consider using the services of a professional auto radio installer.

Kenwood KTC-HR100TR HD Radio Adapter

An external adapter unit that adds HD Radio reception capability to a variety of Kenwood after-market in-dash auto radio "head units." Can *only* be used with compatible Kenwood radio models. Download this Kenwood brochure (.PDF file) to confirm which currently available radios are compatible with the KTC-HR100TR.

Availability:

- national web retailers—Crutchfield.com, Amazon.com, etc.
- specialist automobile audio dealers
- introduced in 2004
- list price: $399.99, available at discount for $200 or less
- a $40 rebate is available to consumers who purchase a KTC-HR100TR adapter between 29 April and 3 July 2007; the rebate form can be downloaded here

Features:

- models KTC-HR100TR and KTC-HR100MC are fully Multicast-capable, offering reception of additional HD Radio program channels (HD-2, HD-3); the earliest KTC-HR100 (no suffix) version was NOT capable of Multicast reception
- Multicast channels can be stored as station presets
- control and display functions are dependent on the capabilities of the Kenwood in-dash radio used with the KTC-HR100TR adapter
- one year limited warranty

Performance:

- excellent FM sensitivity when properly installed in any vehicle incorporating a good original equipment radio antenna
- good AM sensitivity
- excellent audio quality when paired with a high-quality Kenwood in-dash radio

- displays program information (PSD) for HD stations when paired with an appropriate Kenwood in-dash auto radio

Installation:

- will require use of a Kenwood in-dash radio; professional installation recommended
- in-dash radio head unit wiring and installation kits for many vehicle makes and models are available from some vendors
- professional installation service may be available from some local dealers; units purchased through Crutchfield.com can be installed professionally for a pre-arranged fee through Crutchfield's InstallCard program; similar prepaid installation programs may be available from other online and mail order vendors

Notes:

- early model KTC-HR100 units lacking a "TR" or "MC" suffix may still be available from some dealers; KTC-HR100 (no suffix) units are NOT Multicast-capable; we recommend you confirm the exact model number of the adapter you are purchasing, and avoid the original KTC-HR100 version
- installation of the unit defeats remote control function of Kenwood in-dash auto radios (if originally provided)
- the HD Radio adapter defeats the radio data service (RDS) display on Kenwood in-dash radios that are designed to provide RDS capability

Resources:

- Manufacturer's website (web link)
- Users manual (.PDF file)
- Catalog and data sheet (.PDF file)

JVC KD-HDR1 Aftermarket Auto Radio

A full-function, stand-alone HD Radio receiver for autos

Availability:

- national web retailers—Crutchfield.com, Amazon.com, etc.

- some automobile audio dealers
- introduced in 2006
- list price: $199.95, often available at a modest discount
- a $40 rebate is available to consumers who purchase a KD-HDR1 radio between 29 April and 3 July 2007; rebate form can be downloaded here (.PDF file)

Features:

- fully Multicast-capable—offers reception of additional HD Radio program channels (HD-2, HD-3); Multicast channels must be selected after tuning to their host station
- "one-piece" installation—no separate HD Radio adapter unit required; standard single-DIN size fits in space used by many original equipment auto radios
- supports four loudspeakers; includes SRS 'CircleSurround Auto' surround sound decoding (requires separate front and rear speakers)
- conventional rotary volume control allows for easy adjustment of sound level
- search and scan control for station and Multicast channel selection
- 18 FM and 6 AM presets available to store station frequencies; presets do not store Multicast channels
- multi-band audio equalizer with user adjustment storage
- colorful digital display shows time, station frequency and call-letters and program information (PSD) for HD stations; analog radio data service (RDS) is not supported
- includes limited-function remote control
- built-in slot-loading disc player supports Compact Discs, recordable compact discs, and discs with MP3 and Windows Media Audio content
- can receive SIRIUS or XM satellite radio when equipped with an extra-cost external satellite receiver unit
- line-level audio input adapters available as options
- one year limited warranty

Performance:

- excellent FM sensitivity when properly installed in any vehicle incorporating a good original equipment radio antenna; good AM sensitivity
- very good audio quality playing HD Radio, standard analog radio and supported audio disc formats

Installation:

- requires replacement of existing auto radio; professional installation recommended
- wiring and installation kits for many vehicle makes and models are available from specialist vendors such as Crutchfield.com
- professional installation service may be available from some local dealers; units purchased through Crutchfield.com can be installed professionally for a pre-arranged fee through Crutchfield's InstallCard program; similar prepaid installation programs may be available from other online and mail order vendors

Resources:

- Manufacturer's website (web link)

Directed HD Car Connect Aftermarket Auto Adapter

(model number DMHD10001)

Aftermarket adapter that allows HD Radio reception to be added to most existing auto radios.

Availability:

- national web retailers—Crutchfield.com, Amazon.com, etc.
- some automobile audio dealers
- introduced in November 2006
- list price: $199.95, may be available at a modest discount
- a $40 rebate is available to consumers who purchase a Directed Car Connect auto adapter radio between 29 April and 3 July 2007; rebate form can be downloaded here (.PDF file)

Features:

- functions as both an HD Radio and as a conventional analog radio; does not require removal or modification of existing equipment; doesn't interfere with use of the automobile's existing radio
- fully Multicast-capable—offers reception of additional HD Radio program channels (HD-2, HD-3)
- "black box" HD tuner is connected between auto antenna and existing radio; delivers audio to the existing car radio via a wired FM modulator; for better audio quality the HD tuner's output can be connected to an existing line-level audio input on the car radio if one is available
- compact controller module with illuminated display can be mounted at any convenient location; provides full control of the HD adapter; search and scan control for digital and analog stations;
- buttons provided for 5 FM and 5 AM presets
- digital display shows station frequency and call-letters and program-related text information (PSD) for HD stations and RDS for analog stations
- includes a compact remote control
- thirty day limited warranty

Performance:

- excellent FM sensitivity when properly installed in any vehicle incorporating a good original equipment radio antenna; good AM sensitivity
- delivers very good audio quality for HD Radio and standard analog radio

Installation:

- requires wiring to the existing auto radio and the automobile's electrical supply; professional installation recommended
- professional installation service may be available from some local dealers; units purchased through Crutchfield.com can be installed professionally for a pre-arranged fee through Crutchfield's InstallCard program; similar prepaid installation programs may be available from other online and mail order vendors

Note:

- unit must be carefully grounded to vehicle's power source and chassis; failure to provide a good ground connection will result in unacceptably distorted audio

Resources:

Manufacturer's website (web link)

Component Audio Tuners

HD Radio receivers intended to be used with existing audio systems

Sangean HDT-1 Tuner

A component tuner that offers HD Radio and analog radio reception capability for existing audio systems such as home stereos and home theater systems when connected to the line-level inputs of an external amplifier.

Availability:

- NPR Shop (web link)
- national web retailers—Crutchfield.com, Amazon.com, etc.
- introduced in late 2006
- list price: $199.99; discounts not widely available at this time
- a $40 rebate is available to consumers who purchase a KTC-HR100TR adapter between 29 April and 3 July 2007; the rebate form can be downloaded here (.PDF file)

Features:

- fully Multicast-capable—offers reception of additional HD Radio program channels (HD-2, HD-3);
- presets for 20 FM and 20 AM stations; Multicast channels can be stored as presets
- displays program information (PSD) for HD stations and RDS for analog stations
- offers AM stereo reception for the limited number of stations providing this service
- internal power supply (no external power supply device required)
- one year limited warranty

Performance:

- excellent HD FM sensitivity when used with the provided "T" antenna or an external antenna
- good AM HD sensitivity when used with the provided AM antenna
- excellent audio quality delivered through line-level stereo outputs (rear panel phono jacks)

Installation:

- must be connected to an external amplifier and loudspeakers such as a component stereo or home theater system; confirm that your audio system has an unused line-level audio input available before purchasing this unit

Notes:

- early production units deliver a relatively high audio output level that may overload some amplifiers; contact Sangean if you experience unusual audio distortion when using this tuner
- the time-of-day clock in some early production units may not keep accurate time; contact Sangean if you experience this problem
- no headphone jack provided
- display cannot be dimmed; user may find the display to be too bright for use in bedrooms, etc.

Resources:

- Manufacturer's website (web link)
- Users manual (as a .PDF file)
- Data sheet (as a .PDF file)

NATIONAL PUBLIC RADIO

Report to the Corporation for Public Broadcasting

Digital Radio Coverage & Interference Analysis (DRCIA) Project: Analog Radio Receiver Performance Report Deliverable 6.7

CPB Account No. 10446
Reporting Date: July 23, 2007

INTRODUCTION

NPR is pleased to present the Corporation for Public Broadcasting this interim report on Analog Receiver Performance Tests for the Digital Radio Coverage and Interference Analysis project. This update reviews NPR's ongoing development of the measurement Test Bed, the selection of receivers, and preliminary results of the receiver measurements.

NPR'S TESTING OF ANALOG FM RECEIVERS (DELIVERABLE 6.7)

Selections for Receivers

NPR Labs plans to measure at least 45 receivers for reception performance and interference susceptibility using combinations of analog FM and IBOC signals. Through special arrangement with the Consumer Electronics Association, NPR Labs is using receivers selected by the CEA and National Radio System Committee, as current consumer products representing the major radio categories: Home Stereo, Portable, Shelf/Mini-System, Table Radio, OEM Car, and After-Market Car. There are 30 receivers in this category, listed in Appendix A. In addition, we plan to measure the analog receiver performance of IBOC receivers, using the 15 receivers already tested recently for IBOC reception as listed in Appendix B.

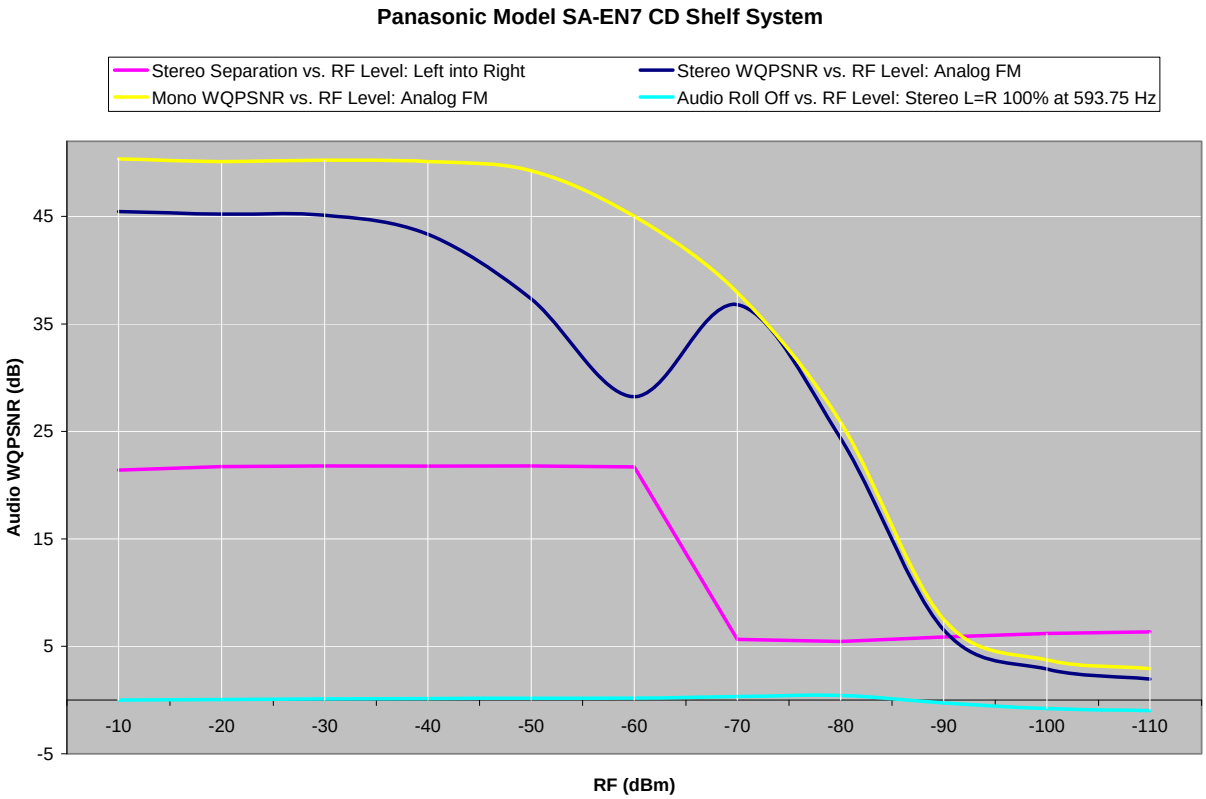
RECEIVER TEST BED INSTRUMENTATION

We have completed construction of the receiver Test Bed and development of MATLAB software to automate the measurements of each receiver. We are collecting scores of different data points for each receiver, including sensitivity, interference susceptibility from analog and hybrid sources, and performance under conditions of impairment.

The receiver measurements are underway as of this report, and complete data is being collected. This section of the project was delayed in part by the unforeseen technical issues with commercial field measurement instrumentation for the station measurements program, which required new instrumentation to be developed. Fortunately, those issues were overcome and the IBOC station measurement data, as well as the development of an IBOC coverage and interference prediction model, is nearing completion with excellent results. Also, as discussed below, we encountered complexities in the behavior of many consumer receivers that required considerable revision and retesting of the MATLAB code running the measurements.

An example of the receiver performance variations we discovered is shown below for a typical Shelf/Mini-System receiver. This graph shows the monophonic and stereo signal-to-noise ratio versus RF level, along with the stereo separation and audio level change with RF level. It is apparent that the monophonic SNR (in yellow) declines smoothly with decreasing RF level, while the stereo SNR (in blue)

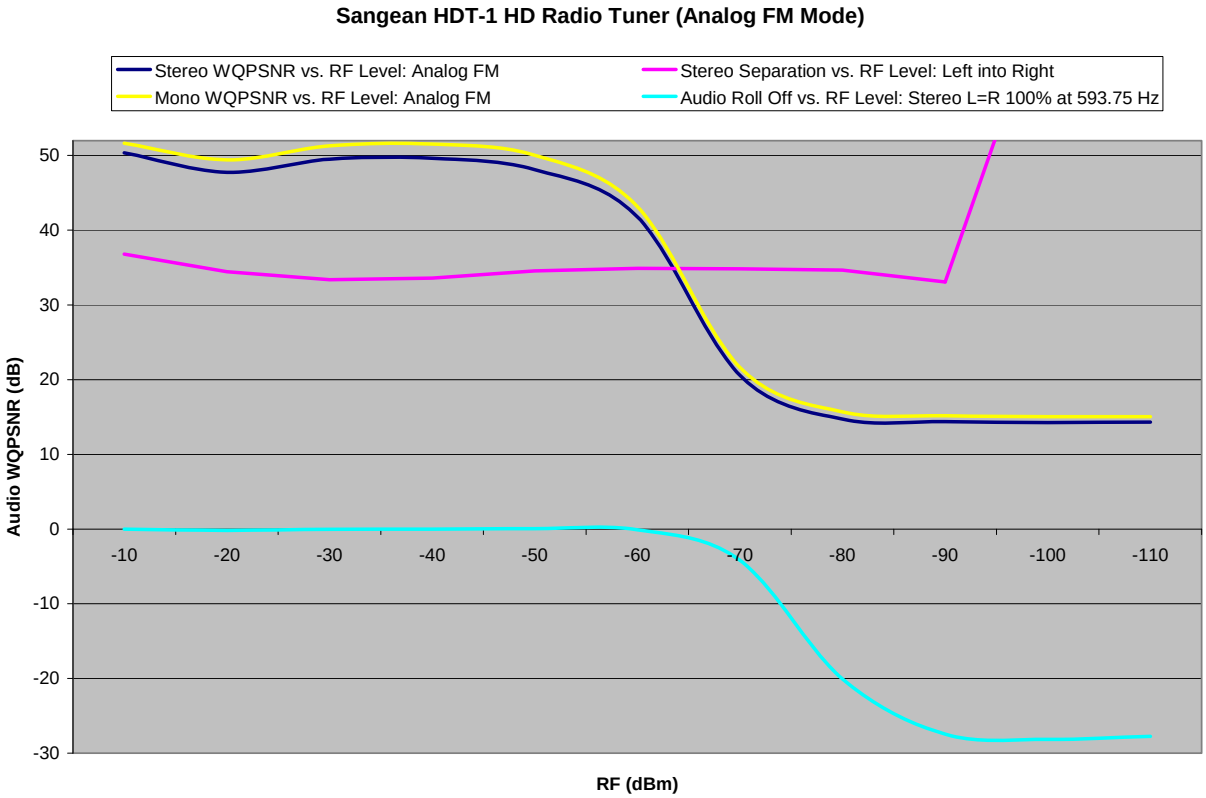
does not. In fact, there are RF levels at which the same audio SNR is achieved three times. This is caused by a stereo blending technique in this receiver, which causes an improvement in SNR at the expense of stereo separation (in purple). This effect may improve reception quality under some conditions, but it can lead to erroneous measurement results with both manual and automated measurement processes.



Another example of complicated receiver behavior, which can produce erroneous measurement data, is shown below. This graph shows the same analog FM audio measurements for a Sangean HDT-1 IBOC tuner, but with quite different results. While stereo separation at low frequencies remains constant to approximately -90 dBm (again, in purple), which is a very low signal power, this receiver employs high-frequency roll off to attenuate the audio SNR, starting at -50 dBm, a relatively strong signal.

This tuner also employs “soft muting” to attenuate the middle audio frequencies below -60 dBm, as shown by the turquoise curve. Comparison with the previous receiver shows a very different behavior in audio output versus RF level.

The resulting changes in audio must be determined and dealt with before interference testing. Consequently, we have researched and tested additional programming in our software to ensure that these noise and interference reduction techniques do not mislead our measurements or skew our results. This has required considerable extra time, but we are confident the work has been worth it.



While some receivers have already completed the measurement process, we feel it would be misrepresentative to present final results with a small population of data. Actually, the variability in unit performance we have noted so far reinforces our decision to test a large number of receivers to understand the effects of interference-free and interference-limited coverage, which is necessary for the mapping portion of this project. We have discussed our issues and our progress with Doug Vernier (on July 20) and Brian Gibbons (on July 23) and they understand that good progress is being made, although we expect to complete the analog receiver performance measurements later than the original project schedule of July 23rd. We will continue to move forward with the receiver measurement process and look forward to reporting and discussing all the results with CPB soon.

Appendix A – Analog Receivers for Test

Category	Brand	Radio Description	Model
Home stereo	Sony	700W 7.1-Ch. A/V Home Theater	STRDE697
Home stereo	Yamaha	600W 6.1-Ch. A/V Home Theater	HTR-5740
Home stereo	Denon	AM/FM multimedia	DRA-295
Home stereo	Pioneer	600W 6.1-Ch. A/V Home Theater	VSX-D814K
Home stereo	Denon	High Performance AM Stereo/FM Stereo	TU-680NAB
Shelf/mini system	Panasonic	CD Bookshelf Stereo	SC-EN7
Shelf/mini system	Sony	Desktop Micro System	CMTNE3
Shelf/mini system	Bose	Wave Music System	CD/AM/FM
Shelf/mini system	RCA	Bookshelf System	RS23035
Portable CD	Sony	400W Mini Hi-Fi Stereo CD Changer	MHCGX450
Portable CD	Emerson	Portable CD Boombox	PD6810
Portable CD	Panasonic	Mini AM/FM Stereo Cassette Recorder	RXFS430A
Portable CD	Aiwa	Hi-Fi Mini System - Silver	JAX-S77
Portable CD	Grundig	AM/FM Shortwave World Band	S350
Portable CD	GE	Super Radio III	360678
Portable CD	CCRadio Plus	Large portable	CCRadio Plus
Car in-dash CD	Pioneer	AM/FM/CD	DEH-P6600
Car in-dash CD	Kenwood	AM/FM/CD	KDC-3025
Car in-dash cassette	Sony	AM/FM Cassette	XR-F5100X
Car in-dash cassette	JVC	AM/FM/Cassette	KS-FX490
OEM auto	Chevrolet	1995 Camaro	16175961
OEM auto	Chevrolet	2000 Tahoe	15765006
OEM auto	Chevrolet	2002 Suburban 2500	15071234
OEM auto	Ford	2002 Mustang	2L2T-18C868-DA
OEM auto	Honda	2002 Accord	39100-S84-A410-M1
Clock	Boston Acoustics	Recepter Digital AM/FM Dual Alarm	Recepter-P
Clock	Curtis	CD AM/FM Stereo Clock	CR4966
Clock	Sima	NOAA Alert AM/FM & Alarm Clock	WX-39
Clock	Audiovox	Electronics CD AM/FM Alarm Clock	CE256
Portable CD	RCA	Boom box type	RCD147

Appendix B – IBOC DAB Tuners and Radios for Analog Test

Category	Brand	Model	Serial No.	date rcvd
auto adapter	AGT/Visteon	HD Zoom HDZ300	KYZ20721000913	20070618
auto after-market	JVC	KD-HDR1	101X0211	20060600
auto after-market	Kenwood	KTC-HR100TR	40400009	2005*
auto/home transportable	AGT/Visteon	HD Jump HDP250	KYJ0716000884	20070618
component tuner	Rotel	RT1084	813-6321192	20070131
component tuner	Sangean	HDT-1	6A012004	20070400
professional	DaySequerra	M2	D70137	2006*
tabletop	AGT/Visteon	HD Pulse HDT200	JH0701900234	20070618
tabletop	Boston Acoustics	HD Recepter	AFQ5D001502	20051100
tabletop	Cambridge SoundWorks	820HD	0049-1307010517	20070621
tabletop	Directed Electronics	DHHD-1000	DH61200003009	20070400
tabletop	Polk	I-Sonic	AM112504261	20061000
tabletop	Radio Shack	Accurian	none	20061000
tabletop	Radiosophy	HD100	n/a	20070707
tabletop	Sangean	HDR-1	6A019569	20070400

* Programming ROM was re-flashed with latest production firmware.